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THE SIGNIFICANCE OF STRUCTURE IN THE ACCUMULATION OF OIL IN TENNESSEE[1]

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ABSTRACT

A review of the data obtained in the several fields in Tennessee which are now producing or have produced oil in commercial quantities shows that in nearly all of them "structure" plays an essential part in the accumulation of oil and gas. Other factors are just as essential and must be taken into consideration. Nearly all of the fields have been mapped in sufficient detail to show the relative importance of the attitude of the beds. Only in the Spring Creek field is this factor apparently of little consequence.

The results of detailed mapping warrant the additional statement that the chances are overwhelmingly against wells located without regard to structure. Not all of the favorable structures drilled have produced oil, but all of the definitely unfavorable ones have been failures.

Anticlinal domes provide oil in the following fields: Celina and vicinity, including Mill Creek and Willow Grove, Spurrier-Riverton, Sumner County, and Tinsleys Bottom. The Glenmary field is on a low-faulted anticline, and the Bone Camp field near Sunbright is on a terrace. The data are none too satisfactory for the Spring Creek field, the Glenmary field, and part of the production of the Willow Grove and Spurrier-Riverton fields.

INTRODUCTION

The oil produced in Tennessee has been obtained from porous or cavernous limestones ranging from 300 feet above to 700 feet below the Chattanooga shale. The strata within this 1,000-foot section are principally of Ordovician and Mississippian age. The oil has been localized in nearly every field by small domes of little closure.

[1] Paper presented by title before the Association at Tulsa, March 26, 1927. Published by permission of the state geologist of Tennessee.

[2] Department of Geology and Geography. Dr. Lusk died in July, 1927.

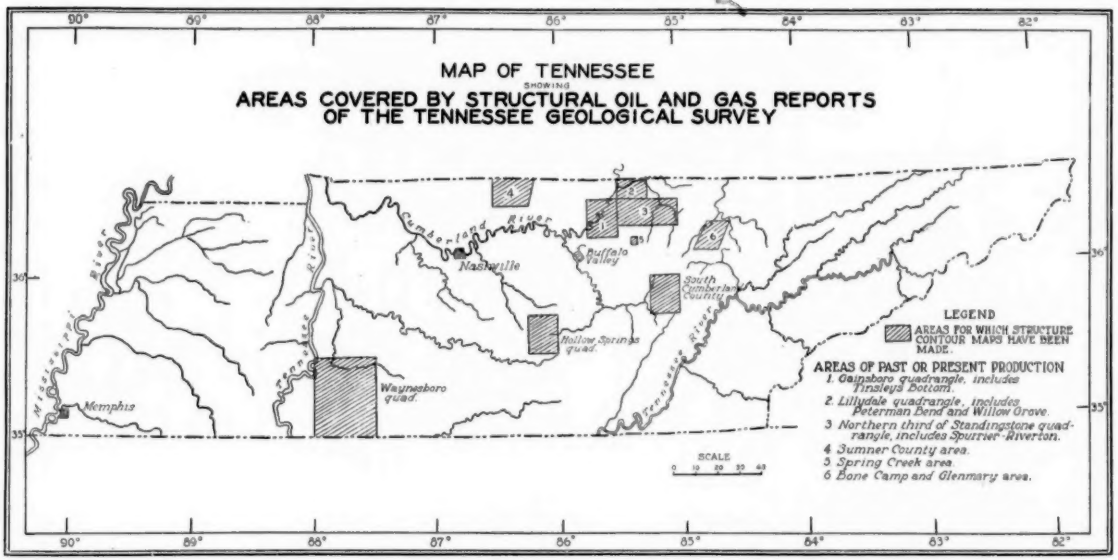
MAP OF TENNESSEE
SHOWING
AREAS COVERED BY STRUCTURAL OIL AND GAS REPORTS
OF THE TENNESSEE GEOLOGICAL SURVEY
90°
89°
88°
87°
86°
85°
84°
83°
82°
36°
35°
Mississippi River
Memphis
Obion River
Waynesboro quad.
Cumberland River
Nashville
Buffalo Valley
Hollow Springs quad.
South Cumberland County
Tennessee River
LEGEND
AREAS FOR WHICH STRUCTURE CONTOUR MAPS HAVE BEEN MADE.
AREAS OF PAST OR PRESENT PRODUCTION
1. Gainsboro quadrangle, includes Tinsleys Bottom.
2. Lillydale quadrangle, includes Peterman Bend and Willow Grove.
3. Northern third of Standingstone quadrangle, includes Spurrier-Riverton.
4. Sumner County area.
5. Spring Creek area.
6. Bone Camp and Glenmary area.
SCALE
0 10 20 30 40

FIG. 1

The state of Tennessee, in its great length, extends from the highest part of the southern Appalachians to Mississippi River (Fig. 1). It thus lies across the lines of the southwestward extension of the Cincinnati Arch, on the flanks of which are the oil and gas fields of central Ohio and of the Lima, Indiana, area. Moreover, strata and general structure similar to those from which oil is produced in the Cretaceous fields of Arkansas and Louisiana are present on the opposite side of the Mississippi embayment in Tennessee. The development of Tennessee's petroleum resources, however, must be dependent upon painstaking analytical studies of the conditions of the accumulation of the oil that has been produced, and a searching investigation of any problems that may develop as peculiar to oil fields within the state. The present paper briefly summarizes the accumulated data pertaining to individual fields with special reference to producing horizons and structure.

PRODUCING HORIZONS AND OIL FIELDS

Rocks from nearly every geologic period are present in Tennessee, but the producing horizons of proved commercial importance are very few (Fig. 2).

KNOX DOLOMITE

Many wells throughout the Central Basin and a few elsewhere in the state have explored the Knox dolomite and have found a few "showings" of oil and gas. Of the wells reported to have reached that formation, only the Holbert Creek well, drilled in 1921, produced oil or gas in anything like commercial amounts. That well is located on the Sells farm, in the extreme eastern part of Pickett County, two miles northeast of Moodyville. The stratum from which the oil is obtained is 65 feet thick. It is 1,335 feet below the Chattanooga shale and 800 feet below a thin but widespread layer of volcanic ash, referred to by drillers as the "Pencil cave."[1] According to Nelson, who examined samples of the oil and cuttings, this horizon may be the upper Knox dolomite, but is more likely to be a zone slightly above the base of the Ordovician.[2]

ORDOVICIAN HORIZONS

Accepting that conclusion, the oil-yielding beds at Holbert Creek may represent the basal part of the Stones River group in the lowermost Or-

[1] Wilbur A. Nelson, "Notes on a Volcanic Ash Bed in the Ordovician of Middle Tennessee," *Tenn. Geol. Survey Bull. 25* (1921), pp. 46–47.

[2] Wilbur A. Nelson, "Description of Oil and Gas Areas in Tennessee and Conditions Affecting New Areas," *ibid.*, pp. 57–58; "The Oil Horizons of Kentucky, Northeastern Mississippi, and Tennessee," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 5 (1924), pp. 622–24.

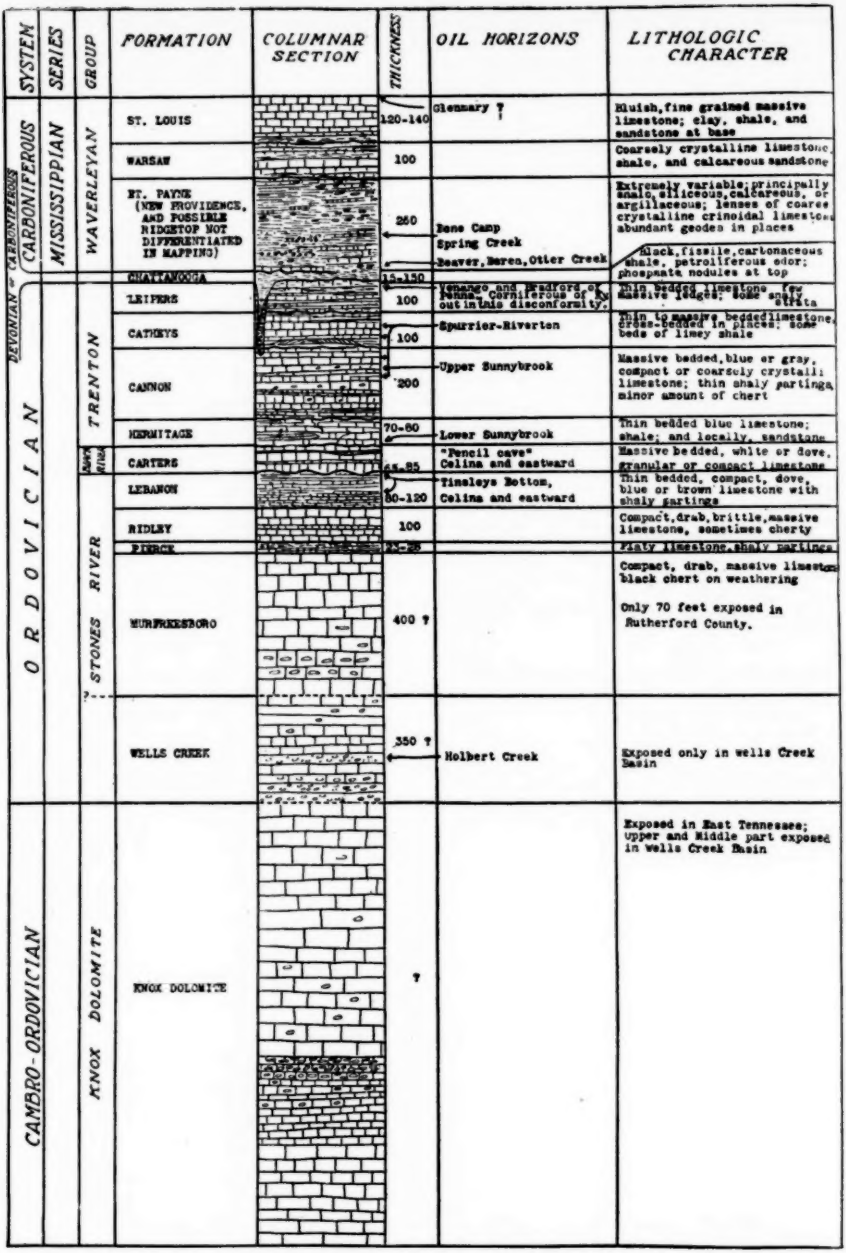

FIG. 2.—Generalized columnar section for northeast middle Tennessee. Typical of the strata on the northeast flank of the Nashville dome. Rocks below the upper 70 feet of the Murfreesboro formation are not exposed in the Central Basin. The Fort Payne, Warsaw, and St. Louis formations appear at the surface of the Highland Rim Plateau. Six hundred feet of higher Mississippian strata and 600 to 1,200 feet of the lower beds of the Pennsylvanian series are pierced in wells drilled on the Cumberland Plateau before the top of this column is reached. The rocks of the Sumner County area differ slightly from those to the east, for the section on the northwest flank of the Nashville dome includes Silurian strata with a thickness ranging from a few to a few hundred feet; moreover, the upper part of the Ordovician system does not correspond exactly with that shown in this figure.

dovician. Subsurface correlations of Ordovician strata are, however, very unsatisfactory, since as yet no extensive analytical study of drill cuttings has been made. Correlation has been based largely upon depth below the Chattanooga shale or the position relative to the "Pencil cave." The good showing at Holbert Creek has not led to any further discoveries and there is no field producing from this deep horizon.

"Showings" are reported from various strata higher in the Ordovician system. The lowest horizon of commercial production is at Tinsleys Bottom, where the main yield is from a zone 90 to 100 feet in thickness and from 50 to 150 feet below the "Pencil cave." If this bed of volcanic ash is high in the Carters limestone, then, by using the average thickness of strata as measured by Galloway in Rutherford County, this oil-yielding zone may be correlated with the Lebanon limestone.[1] The highest production of importance at Tinsleys Bottom is reported from a zone 50 to 60 feet below the "Pencil cave," which may well represent approximately the contact of the Carters with the Lebanon formation.

Tinsleys Bottom Oil Field.[2]—The Tinsleys Bottom oil field, developed in 1924–25, is on the Clay–Jackson County line between Celina and Gainesboro. Leipers strata, of Ordovician age, are the oldest rocks appearing at the surface in the immediate area. The Chattanooga shale and younger Mississippian beds are exposed on hill slopes which rise to the surface of the Highland Rim Plateau, here dissected by Cumberland River and its tributaries. Ordovician strata younger than Leipers, and Silurian and Devonian formations, do not appear on the northeast flank of the Nashville dome and are not represented here.

The general structure is a gently plunging northward extension of the Nashville dome. The oil field is located on a well-defined anticlinal fold, as indicated by the elevations of the "Pencil cave" obtained from well logs, and of the Chattanooga shale at outcrops on the adjacent hillsides. The probably productive part of the dome extends about a half-mile east and west, and a quarter of a mile north and south, although only about one-third of the area has been drilled, and its closure probably exceeds 50 feet. The absence of the Chattanooga shale over the area of the dome makes impossible the determination of the date of the folding of the Ordovician strata, which may have occurred either before or after the deposition of

[1] J. J. Galloway, "Geology and Natural Resources of Rutherford County, Tennessee," *Tenn. Geol. Survey Bull. 22* (1919), pp. 30–31.

[2] Joseph K. Roberts, *Tenn. Geol. Survey Press Bull.*, March 15, 1926. Ralph G. Lusk, "Geology and Oil and Gas Resources of the Gainesboro Quadrangle, Tennessee, *ibid.*(report in preparation).

the shale. If the data from the "Pencil cave" and dips in the limestone were not available, so that one depended solely upon the elevations of the Chattanooga shale, the area could be contoured as a broad shallow syncline, although the oil field itself would lie in a portion of the region in which the lines would be drawn by extrapolation from surrounding areas.

Shows of oil and limited production have been obtained from 10 to about 300 feet below the "Pencil cave," but, as previously mentioned, the main production is between 50 and 100 feet below this formation, or approximately 550 to 650 feet below the Chattanooga shale. The history of adjacent wells records the fact that one has interfered with the other; and there is the account of a single well that had been standing with several hundred feet of flouid in it, suddenly becoming dry. This suggests cavernous conditions with interconnecting channels.

In 1925, 8,500 barrels, and in 1926, about 7,000 barrels of oil were produced from this field. This was pumped through the pipe line of the Stoll Oil Refining Company to the town of Windle, which is on the Tennessee, Kentucky, and Northern Railroad. Early in 1926 the production declined to about 15 barrels a day. At the present time no drilling is being done, but activities will probably be resumed in the near future.

The "Pencil cave" formation may be in the upper part of the Carters limestone, which probably attains a thickness of 60 to 80 feet, including 15 to 25 feet of strata above the base of the lower division of the "Pencil cave."

Oil Fields of Celina and vicinity.[1]—The general topographic and structural conditions noticed at Tinsleys Bottom are observed in the small areas east of Celina.

The production from the dozen wells at Peterman Bend along Obey River (Fig. 3) is said to be derived from the few feet of strata separating the upper and lower divisions of the "Pencil cave."[2] This small field is on an anticline of slightly smaller dimensions than the one at Tinsleys Bottom.

What may well be the contact of the Hermitage and Carters limestones, 15 to 25 feet above the base of the "Pencil cave," is called the "Second (or lower) Sunnybrook" by local drillers. Production, on which separate figures were not obtained, is derived from this horizon and a still higher horizon, the "First (or upper) Sunnybrook," from small anticlines in the Willow Grove area on Obey River and two small, but well-defined

[1] Gene Perry, *Tenn Geol. Survey Press Bull.*, Dec. 14, 1925. (With structure map.) Field notes taken by the writer in summer of 1926.

[2] Deepening of these wells has brought in production below the "Pencil cave."

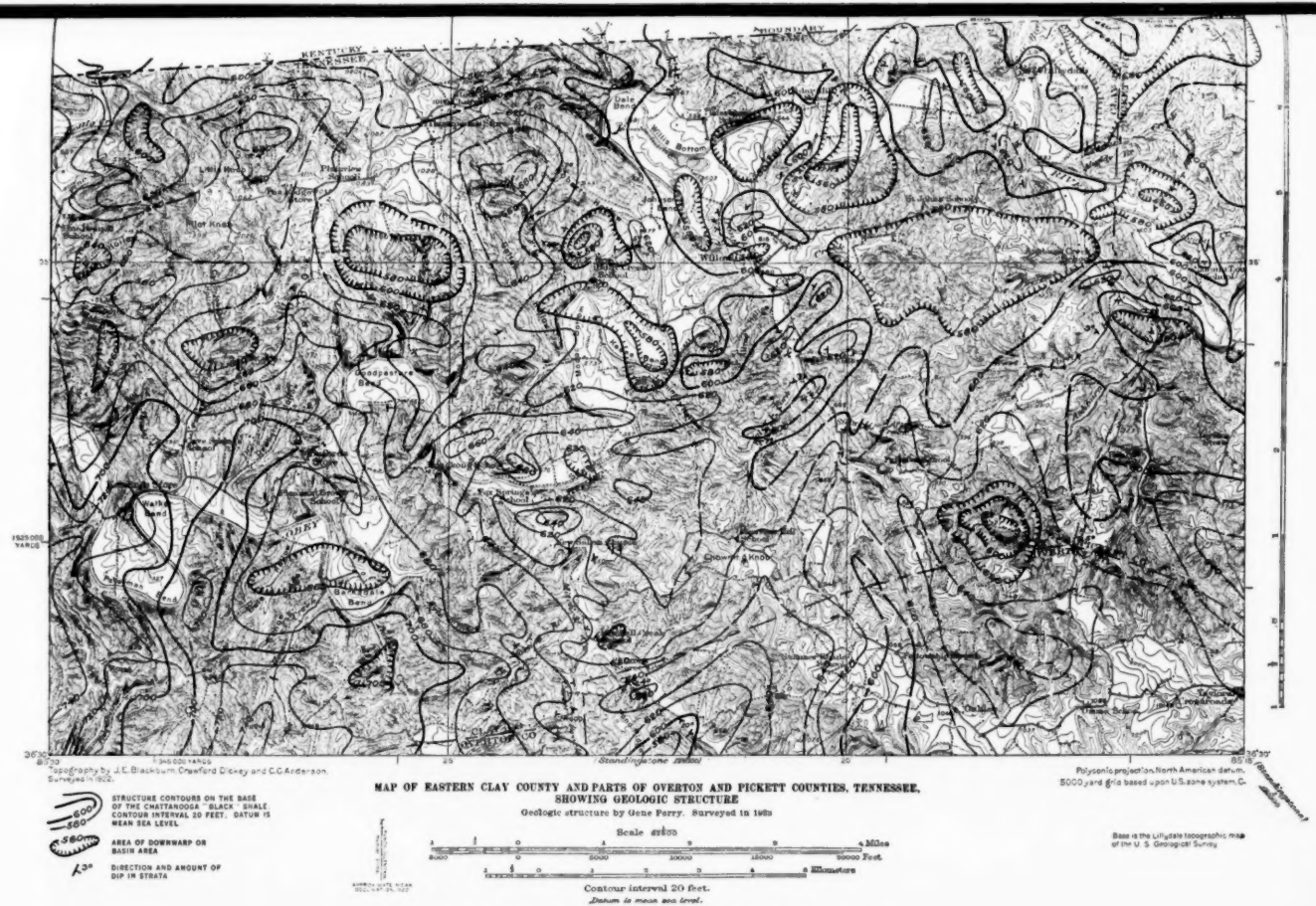
KENTUCKY
TENNESSEE
Topography by J.E. Blackburn, Crawford Dickey and C.C. Anderson.
Surveyed in 1902.
STRUCTURE CONTOURS ON THE BASE OF THE CHATTANOOGA "BLACK" SHALE. CONTOUR INTERVAL 20 FEET. DATUM IS MEAN SEA LEVEL
AREA OF DOWNWARP OR BASIN AREA
DIRECTION AND AMOUNT OF DIP IN STRATA
MAP OF EASTERN CLAY COUNTY AND PARTS OF OVERTON AND PICKETT COUNTIES, TENNESSEE, SHOWING GEOLOGIC STRUCTURE
Geologic structure by Gene Ferry. Surveyed in 1923
Scale 1:62500
Miles
Feet.
Kilometers
Contour interval 20 feet.
Datum is mean sea level.
Polyconic projection. North American datum.
5000 yard grid based upon U.S. zone system.
Base is the Lillydale topographic map of the U. S. Geological Survey

FIG. 3.—From *Tennessee Geological Survey Bulletin 37*

domes on Mill Creek, the latter independently mapped by J. H. McClurkin. The production from Celina and vicinity for 1926 was 6,000 barrels, according to preliminary figures of the United States Bureau of Mines.

The upper Sunnybrook is about 225 feet above the lower Sunnybrook and 250 feet below the Chattanooga shale. This definitely places it in the upper part of the Cannon formation, which was mapped by the writer in the Gainesboro quadrangle during the summer of 1926. The limestone strata 250 to 265 feet below the Chattanooga shale in Poorhouse Hollow, near Gainesboro, possess a coarse texture, with clear crystals of calcite replacing the plentiful fossils. Some of the fossil cavities are filled with oil. The texture is distinctly granular and so produced by recrystallization with an evident increase in the degree of porosity above that of other beds in the section. This horizon may be recognized at other localities within the quadrangle and probably represents the First Sunnybrook of the drillers. The lower limit of the important production in the Spurrier-Riverton field is at this horizon.

Spurrier-Riverton oil fields.[1]—The Spurrier-Riverton oil field is on the Highland Rim Plateau in Pickett County, 12 miles east and a little north of Livingston. Appearing at the surface are Fort Payne strata of Misssippian age which overlie the Chattanooga shale. Below the Chattanooga shale lie the Ordovician formations, also encountered by the drill in the Tinsleys Bottom and Celina areas.

According to Butts's structure map, the field appears to be located where the regional dip toward the southeast abruptly increases. There are many folds in the area mapped and their long axes are generally parallel to the Appalachian structure. For the most part the productive wells were drilled on small, closed anticlinal folds. Butts states[2] that he could not be certain about those not definitely shown on favorable structure, for the data were not complete.[3]

The production was derived from at least thirteen horizons within 508 feet of strata below the Chattanooga shale, spaced in descending order about as follows: 20, 34, 65, 106, 146, 170, 206, 230, 267, 309, 409, 460, and

[1] M. J. Munn, "Preliminary Report upon the Oil and Gas Development in Tennessee," *Penn. Geol. Survey Bull. 2-E* (1911), pp. 9–16; Charles Butts, "Geology and Oil and Gas Possibilities of the Northern Part of Overton County, Tennessee, and of Adjoining Parts of Clay, Pickett and Fentress Counties," *ibid. Bull. 24*, Part 2-A, 1919.

[2] *Op. cit.*, p. 44.

[3] In a recent letter, dated March 24, 1927, J. H. Compton, Riverton, Tennessee, writes that oil occurs in a syncline, where the rocks are dry.

508 feet. The main horizons are between 170 and 267 feet below the Chattanooga shale, hence principally within the Cannon formation, although perhaps in part in the lower strata of Catheys.

Water conditions proved very troublesome in the operation of the wells and would have ruined the field had it not been for the intelligent management of J. H. Compton, pioneering in 1900 with water control in oil production. The first well was drilled in 1892 and a total of about 80,000 barrels of oil was marketed. A large amount was lost from the phenomenal Bob's Bar well, which ran wild for several months. A combination of circumstances led to the removal of the pipe line in 1906, following which the field was abandoned. There has been no drilling campaign for several years, but recent reports show a small steady production, and the field is apparently merely waiting for favorable conditions for redevelopment.

SILURIAN AND DEVONIAN HORIZONS

Only in Sumner County have the Silurian strata actually produced oil in commercial amounts. There is no production from Devonian strata in Tennessee. In Sumner County, the "Corniferous" limestone of Devonian age, from which oil is produced in adjacent areas in Kentucky, has not been encountered by the drill and it is wanting from the section in outcrops. There are two "sands" in the strata which represent the Silurian system noted as possible producing horizons, one in the Louisville limestone, immediately underlying and in places as much as 50 feet below the Chattanooga shale, and the other in the Laurel limestone, 50 feet lower.

Sumner County oil field.[1]—The southern third of Sumner County is within the Central Basin, and the remainder is on the northern Highland Rim Plateau. Ordovician limestone strata of the Richmond group are the lowest beds exposed. Above them and below the Chattanooga shale are 125 feet of Silurian strata. Above the Chattanooga shale are formations of lower Mississippian age.

The area is on the northeastern flank of the Nashville dome and the low regional dip is toward the north and northwest. This is modified by local flexures of a square mile or two in area, which have determined the location of oil. Wells not on anticlines have proved failures.

The oil production from Sumner County is a southward extension of the Allen County, Kentucky, field, and is obtained from the Louisville and Laurel limestones not more than 100 feet below the Chattanooga shale.

[1] F. Kirtley Mather, "Oil and Gas Resources of the Northeastern Part of Sumner County, Tennessee," *Tenn. Geol. Survey Bull. 24*, Part 2-B, 1920.

These limestones have been found porous enough to form reservoir beds only in part of the wells drilled in Sumner County.

In 1920 several wells were reported as producing from 4 to 25 barrels of oil per day. There is no current activity.

CARBONIFEROUS HORIZONS

The varying character of the first 200 to 250 feet of strata above the Chattanooga shale renders correlation difficult and has led to some confusion in the application of the term Fort Payne, for, as used by different authors, it may or may not include Ridgetop and New Providence.

The production in the Spring Creek formation was derived from the Fort Payne formation, mainly from strata 120 and 150 feet above the Chattanooga shale. The Bone Camp oil is from a porous limestone near or just below the middle of the Fort Payne formation at a distance of about 75 feet above the Chattanooga shale, while that obtained near Glenmary is found about 325 feet higher, probably at the contact of the St. Louis limestone with the overlying Fredonia oölite. "Shows" have been reported but no production in other Carboniferous formations.

Spring Creek oil field.[1]—The Spring Creek oil field is in the southern part of Overton County, 10 miles northeast of Cookeville, and about the same distance south of Livingston. It is on the eastern Highland Rim Plateau. Fort Payne strata appear at the surface dipping gently toward the east. In so far as observed, the oil is located without regard to structure, being found in "crevices" in the Fort Payne formation.

The first well was drilled in 1866 near a small oil seep. At 52 feet it ran wild and is reported to have flowed for three months, the oil being lost. About 3,300 barrels of oil were pumped, 2,600 of them from the horizon of 26 feet before the well was deepened. About 7,000 barrels of oil were obtained from the several wells drilled in the first five years. In 1908 and subsequently, attempts were made to reopen the field. There is some activity in the area today, production being sought from the horizons below the Chattanooga.

Glenmary and Bone Camp oil fields.[2]—The oil fields of Scott and Morgan counties are on the Cumberland Plateau section of the Appalachian Plateau province, near its eastern margin, where the coal-bearing forma-

[1] M. J. Munn, "Preliminary Report upon the Oil and Gas Developments in Tennessee," *Tenn. Geol. Survey Bull. 2-E*, pp. 6-9, 1911; "The Spring Creek Oil Fields," *Resources of Tenn.*, Vol. 2, No. 7 (1912), pp. 273–85.

[2] L. C. Glenn, "The Glenmary Oil Fiels," *Resources of Tenn.*, Vol. 8 (1918), No. 3, pp. 211–19; Ralph G. Lusk, "The Oil and Gas Possibilities of Morgan County, Tennessee," Report for the *Tenn. Geol. Survey*, in press.

tions of the Pennsylvanian series rest upon the eroded upper Mississippian shales of the Pennington formation. Below these shales, the Glen Dean limestone, the Golconda shale, the Cypress sandstone, the Fredonia and Gasper oölites, the St. Louis limestone, the Warsaw and Fort Payne strata are encountered by the drill before the Chattanooga shale is reached, here 15 to 75 feet thick. Underneath are Ordovician limestones, locally separated from the Chattanooga shale by a few feet of Silurian strata.

The regional dip is toward the east but it is interrupted by small folds and a few faults. The Bone Camp oil field is located on a terrace and the Glenmary field, 4 miles northeast, is on a fold extending about a mile east and west, and cut off on the north by a fault.

The oil in the Bone Camp field is obtained at a depth of 1,400 feet from a porous limestone horizon about the middle of the Fort Payne formation and 75 or 100 feet above the Chattanooga shale. That from the Glenmary field is from strata about 325 feet higher and probably near the top of the St. Louis limestone, where it was rendered cavernous before the deposition of the Fredonia oölite.

Oil was struck near Glenmary in 1916. About 25 wells were drilled in the first few years, but no drilling has been done recently. In 1925, 4,929 barrels of oil were shipped, derived from the 8 wells then producing. In 1926, 3,920 barrels were marketed.

The first well of the Bone Camp field was drilled on the Drake farm in 1924. Several wells were drilled in 1924–25 and the field is still being extended. In 1925, 8,930 barrels, and in 1926, 25,400 barrels of oil were shipped.

There are other anticlines in the area; gas is being obtained from two of them and other tests are in progress.

SUMMARY AND RECOMMENDATIONS

A review of the data obtained in the several fields in Tennessee which are now producing or have produced oil in commercial quantities shows that in nearly all of them "structure" plays an essential part in the accumulation of oil and gas. Nearly all of the fields have been mapped in sufficient detail to show the relative importance of the attitude of the beds. Only in the Spring Creek field does this factor appear to be of little consequence. Domes with greater or less closure have localized oil in the following fields: Tinsleys Bottom; Celina and vicinity, including Mill Creek and Willow Grove; Spurrier-Riverton; and Sumner County. The Glenmary field is on a low-faulted anticline, and the Bone Camp field near Sunbright is on a terrace. The data are none too satisfactory for the

Spring Creek field, and for part of the production in the Willow Grove and Spurrier-Riverton fields. That the relationship of oil to favorable structure is not purely fortuitous is established by the fact that in the development of the Bone Camp, Tinsleys Bottom, and other fields the wells located down the dip from areas of production have been failures or very small pumpers.

The results of detailed mapping warrant the statement that the chances are overwhelmingly against wells located without regard to structure. Not all of the favorable structures drilled have produced oil, but all of the definitely unfavorable ones have been failures.

Judging from the past and present oil fields, the most favorable places to drill for oil are on the northern and eastern Highland Rim Plateau, on the small anticlines on the flanks of the Nashville dome, and on the Cumberland Plateau between Oneida and Crossville.

In the endeavor to promote any possible extension of the areas of production the State Survey has had structure maps made of some areas, or has directed attention toward definite structures in several reports. Some of this mapping as well as part of the work adjacent to oil fields has been more or less of a reconnaissance type to indicate where more detailed work should be carried on before drilling locations are definitely made.

The attitude of the beds (structure) is not the sole factor to be considered in the search for oil. The nature of reservoir beds is exceedingly important. In the adjacent Glenmary and Bone Camp fields production is obtained at distinctly different horizons separated vertically by 325 feet of strata. This indicates that in the Bone Camp field, so far as the Glenmary horizon is concerned, structure is of no significance; conversely in the Glenmary field, wells drilled on the dome below the local production zone have yielded no oil from the Bone Camp "pay."

There is a crying need for field and laboratory studies in which drill cuttings from producing strata may be studied wherever possible in comparison with actual outcrops of the same or similar beds. The evaluation of the relative importance of structure to other factors may then be made. Source beds and the nature of reservoirs in northeast middle Tennessee are discussed in a report now in preparation for the Tennessee Geological Survey.[1]

The principal areas outside the territory of the oil fields, of which structure maps have been made or in which particular structures have been noted are:

[1] Ralph G. Lusk, "Geology and Oil and Gas Resources of Gainesboro Quadrangle, Tennessee," *Tenn. Geol. Survey* (bulletin in preparation).

Waynesboro quadrangle: Hugh D. Miser, "Structure of the Waynesboro Quadrangle with Special Reference to Oil and Gas," *Resources of Tenn.*, Vol. 7, No. 4 (1917), pp. 199–219; "Mineral Resources of the Waynesboro Quadrangle, Tennessee," *Tenn. Geol. Survey Bull. 26* (1921), pp. 146–52.

Cumberland County: Charles Butts, "Structure of the Southern Part of Cumberland County, Tennessee, in Relation to the Possible Occurrence of Oil and Gas," *Resources of Tenn.*, Vol. 6, No. 2 (1916), pp. 107–10.

Lillydale quadrangle: Gene Perry, structure map of unpublished report for *Tenn. Geol. Survey.*

Hollow Springs quadrangle: R. S. Bassler, structure map of unpublished report.

Benton County: E. S. Perry, "Press Bulletin Report on the Geology and Structural Features of Benton County, Tennessee, as They Affect Oil and Gas Possibilities," *Tenn. Geol. Survey Bull. 25* (1921), pp. 41–45.

Western Tennessee: Wilbur A. Nelson, "Probable Oil Structures in West Tennessee," *ibid. Bull. 23*, Part 1 (1920), pp. 30–38.

West Tennessee River Valley: Carl Dunbar, "Press Bulletin report," *ibid.*, pp. 38–41; "Stratigraphy and Correlation of the Devonian of Western Tennessee," *ibid. Bull. 21* (1919), pp. 21 and 25.

Buffalo Valley: *Tenn. Geol. Survey Press Statement*, July 30, 1926, based on structure map by Ralph G. Lusk.

FLANK PRODUCTION OF THE NEMAHA MOUNTAINS (GRANITE RIDGE), KANSAS[1]

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ABSTRACT

In this report surface and subsurface maps of an area comprising six townships and four producing oil fields are shown. From a comparison of these and a cross-section it is demonstrated that these producing folds are buried hills, and are contemporaneous with the Nemaha Mountains. Surface geology was largely responsible for the development of this area. The subsurface folds are remarkably congruent with the surface structure.

The conclusion is drawn that the surface folds are due to differential settling of the upper horizons over the Ordovician hills. The principal producing horizon is this unconformable contact between the Ordovician and later sediments. Furthermore, it is concluded that the oil has migrated laterally for some distance from its source in the lower Pennsylvanian to its present position.

INTRODUCTION

This report covers four producing oil fields: Elbing, Peabody, Covert-Sellers, and Florence. It embraces an area of six townships: T. 21, 22, and 23 S., R. 4 and 5 E., Butler and Marion counties, Kansas.

The writer is indebted to the Amerada Petroleum Corporation, the National Refining Company, Lee and Garlough of Wichita, Kansas, and to the publications of the Kansas Geological Survey, from which sources he has drawn most of his information.

PHYSIOGRAPHY

Though on the west flank of the Nemaha Mountains[2] these mountains are buried hills, whose surface expressions consist of comparatively small anticlines. That is, these anticlines are small in comparison with the underlying deformation, or in comparison with any mountain-forming folds. However, in comparison with any Mid-Continent oil-producing folds, their proportions are relatively large.

The maximum relief in this territory is probably about 200 feet and

[1] Presented before the Association at the Tulsa meeting, March 25, 1927.
Published by permission of the Amerada Petroleum Corporation.

[2] Raymond C. Moore, "Geologic History of the Crystalline Rocks of Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 2 (1918), p. 112.

with the exception of a few escarpments the slopes of the hills are rather gentle.

HISTORY

The first producing well in this area was Leydig No. 2, the second location south along the east side of the NW. ¼ of Sec. 18, T. 23 S., R. 4 E., in the Elbing field. The date of this discovery was about August 1, 1918.

The discovery in the Peabody field was Elmhurst Investment Company's O. Jolliffe No. 1, located in the south center of the SE. ¼ of the SE. ¼ of Sec. 9, T. 23 S., R. 4 E. This well was completed in September, 1920.

The discovery in the Covert-Sellers field was Ward and Wilhoit's Covert No. 1, located in the southwest corner of the NE. ¼ of the NW. ¼ of Sec. 28, T. 21 N., R. 4 E. This well was completed about the middle of March, 1920.

Almost simultaneously with the discovery in the Covert-Sellers field, Robinson and Loreau brought in their Hupp-Greeley No. 1, located in the southwest corner of the SE. ¼ of Sec. 18, T. 21 N., R. 5 E., thus opening the Florence field.

STRATIGRAPHY

Owing to the comparatively gentle surface dips, a section of 250 feet in thickness will contain all the surface beds exposed in this area. These are all in the lower Permian (non-red) and beginning with the lowest horizon consist of the following limestones with their intervening shales: the limestone beds of the Matfield shales, the Florence flint, the Fort Riley limestone, the Towanda limestone, the Winfield limestone, the Herington limestone, and the limestone bed of the Pearl shales.

With the exception of the two highest horizons, the Herington limestone and the limestone bed of the Pearl shales, these are all very reliable beds. Local dips, which evidently have no bearing on the subsurface structure, are here and there found in the Herington limestone. The limestone bed of the Pearl shales is not continuous and cannot everywhere be found. Fortunately this horizon is exposed only along the western part of this area; hence, its non-continuity interferes but little with the accurate mapping of the structure of the producing areas.

As the normal dip is very slight and the surface folds of the producing fields are small, the recording of local dips for field work is of little benefit. Plane-table methods of mapping have proved the only profitable solution of structure problems in this territory.

In subsurface mapping the Lansing formation is probably the best horizon above the producing zone. This series consists of several hundred

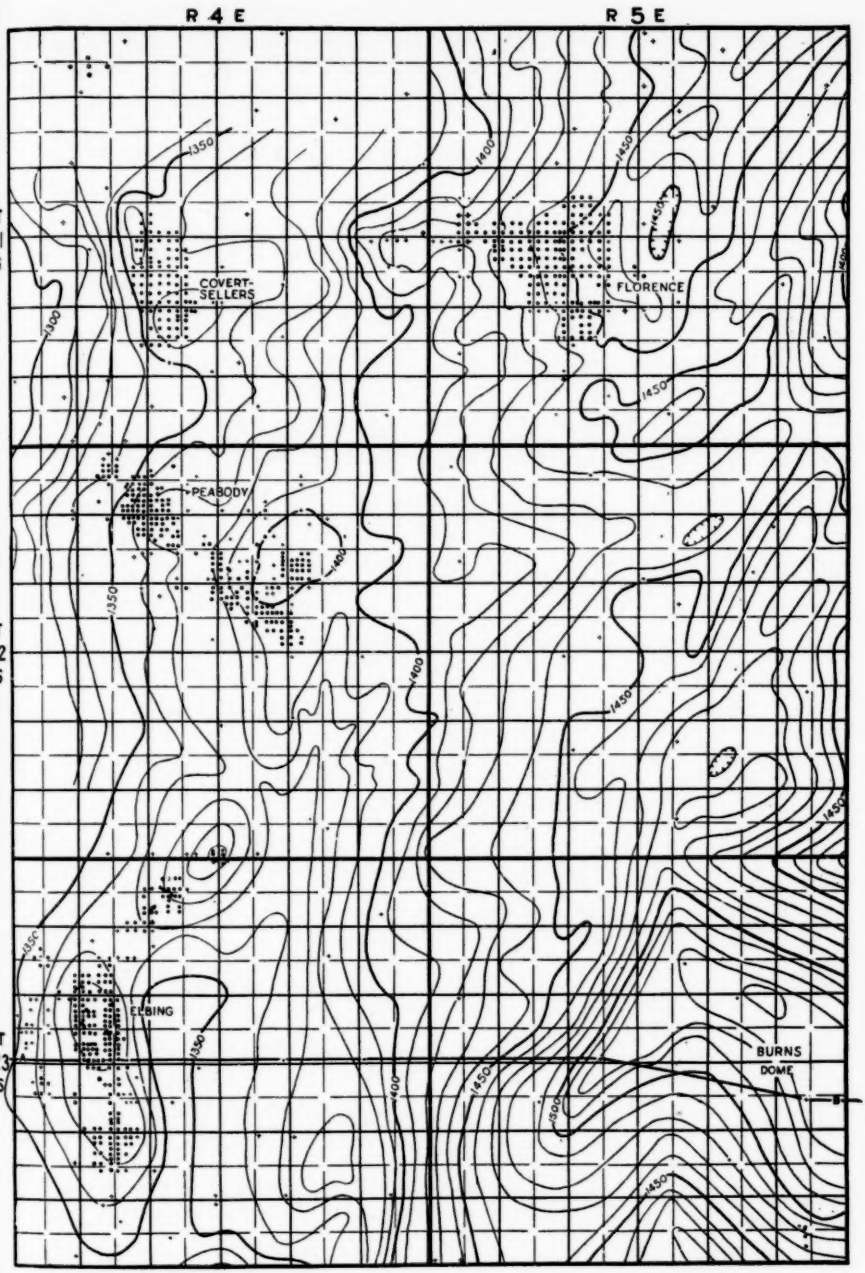

FIG. 1.—Surface structure. Contour interval, 10 ft. Scale, one township approximately 6 miles square. Compilation of work by the Kansas Geological Survey, the National Refining Company, the Empire Gas & Fuel Company, and the Amerada Petroleum Corporation.

feet of thick limestones and may readily be correlated in any well log that has been well kept.

The principal producing horizon is the unconformable contact between the Ordovician and subsequent strata.

SURFACE STRUCTURES

The normal dip in this area is almost due west, and its rate is 15 to 20 feet to the mile. In the area covered by this report, the only buried peak of the Nemaha Mountains is the Burns dome, which lies in the east half of T. 23 N., R. 5 E. (Fig. 1). In the vicinity of this fold the topography in general is a hill. In the producing fields the surface folds are so much smaller that the topography is not noticeably affected by the folding.

Owing to the excellent character of the key horizons used in plane-table mapping, it has been customary to use 5-foot contours in portraying the structure in this territory. The surface structure map accompanying this report is made with 10-foot contours, but was compiled from maps using 5-foot contours. Consequently, with the possible exception of those points where one set of maps has been tied in to another set, this map should be quite accurate.

A very noticeable feature in connection with this surface map is the fact that the production conforms remarkably with the surface structure.

SUBSURFACE STRUCTURES

Two maps of the subsurface structure of this area are given with this report. Figure 2 shows the structure on the top of the Lansing formation. Figure 3 shows the structure on the Ordovician producing horizon. A comparison of these two maps shows the considerably increased intensity of folding of the producing horizon as compared with the Lansing formation. A further comparison with the surface structure shows a considerable slackening in the intensity of these folds as the surface is approached. From these maps it is obvious that the surface folds increase rapidly in size and intensity with depth.

The cross-section A–B (Fig. 4) extending from the Elbing field to the Burns dome demonstrates the considerable shortening of the section over these domes. This shortening appears to be due, not so much to convergence, as to a lack of deposition of the early Pennsylvanian strata (Cherokee shales). The Cherokee appears never to have been deposited on the tops of these folds and the Mississippian series, if deposited, has since been eroded.

The complete section may be found but a few miles east of the peaks of the ridge, although to the west it is many miles before it may be found. Even then the sands of the Cherokee have not yet been discovered.

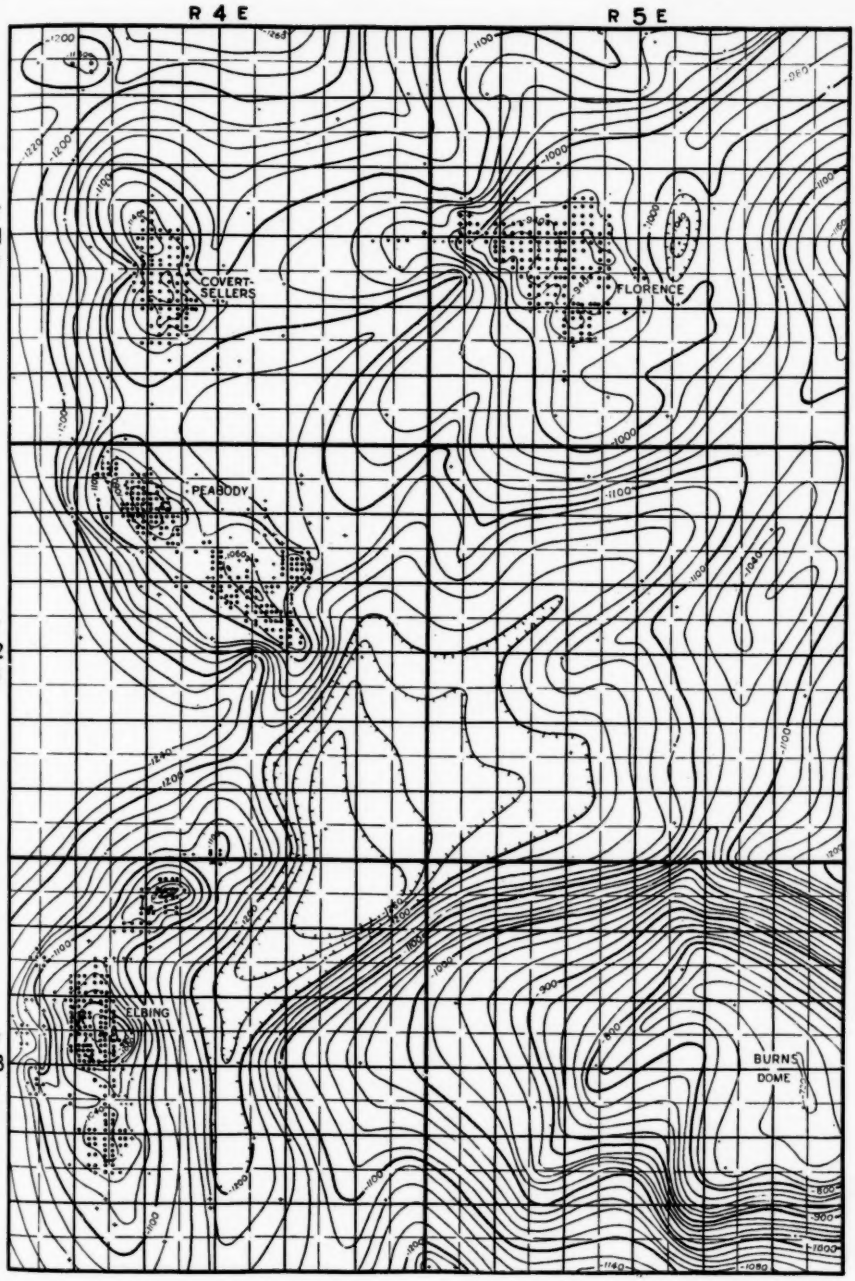

FIG. 2.—Subsurface structure on the Lansing formation. Contour interval, 20 ft. Scale, one township approximately 6 miles square.

The presence of granite in this territory within so short a distance from the surface was entirely unsuspected. In fact, when first encountered with the drill, it was said to be impossible.[1] However, after many granite wells were drilled on the surface highs its presence was demonstrated beyond a doubt. This fact caused a lessening of development in this territory; consequently, it was some years after the discovery of the Augusta and Eldorado fields (which are the two main fields along the axis of the ridge) before the smaller folds along the western flank were drilled.

These subsidiary highs along the western flanks of the Nemaha Mountains are undoubtedly contemporaneous with the larger folds of the ridge proper. Furthermore, their surface expressions are due to the same causes which produced the surface anticlines over the buried granite hills. The surface folds of the flank structures are smaller than the surface folds overlying the granite hills, but the buried Ordovician hills along the flank are much smaller than the buried granite hills along the axis of the ridge.

On both the flank and ridge folds the highest points of the surface folds overlie the highest portion of the buried Ordovician or granite hills. In either case a sharp surface dip indicates a sharp subsurface dip. There are local exceptions to these statements, but in general they hold true throughout this territory.

Taking into consideration the known facts in this area, plus what is known of the entire ridge, the writer can find no adequate explanation of the cause of these structures overlying the buried hills, other than the theory of differential settling. This theory has been adequately expressed by Blackwelder.[2] Some of the facts which give credence to this theory in this area are as follows: the granite hills are not intrusives into the Pennsylvanian but were islands at the time of the deposition of the Cherokee; as the surface is approached the intensity of folding is considerably decreased; the sharp surface dips indicate sharp dips on either the granite or the Ordovician hills which were erosion surfaces; the surface highs indicate peaks on the buried hills; and the absence of surface faulting indicates a lack of lateral strains.

Taking into consideration the facts that obviously more sediments have been deposited in the valleys than on the peaks of this old ridge, and that these sediments were mostly shales, it seems to the writer that these shales must compact with greater age and pressure of the overlying sedi-

[1] Erasmus Haworth, "Crystalline Rocks of Kansas," *Geol. Survey of Kan.*, Bull. 2 (1915).

[2] Eliot Blackwelder, "Origin of the Central Kansas Oil Domes," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 4 (1920), pp. 89–94.

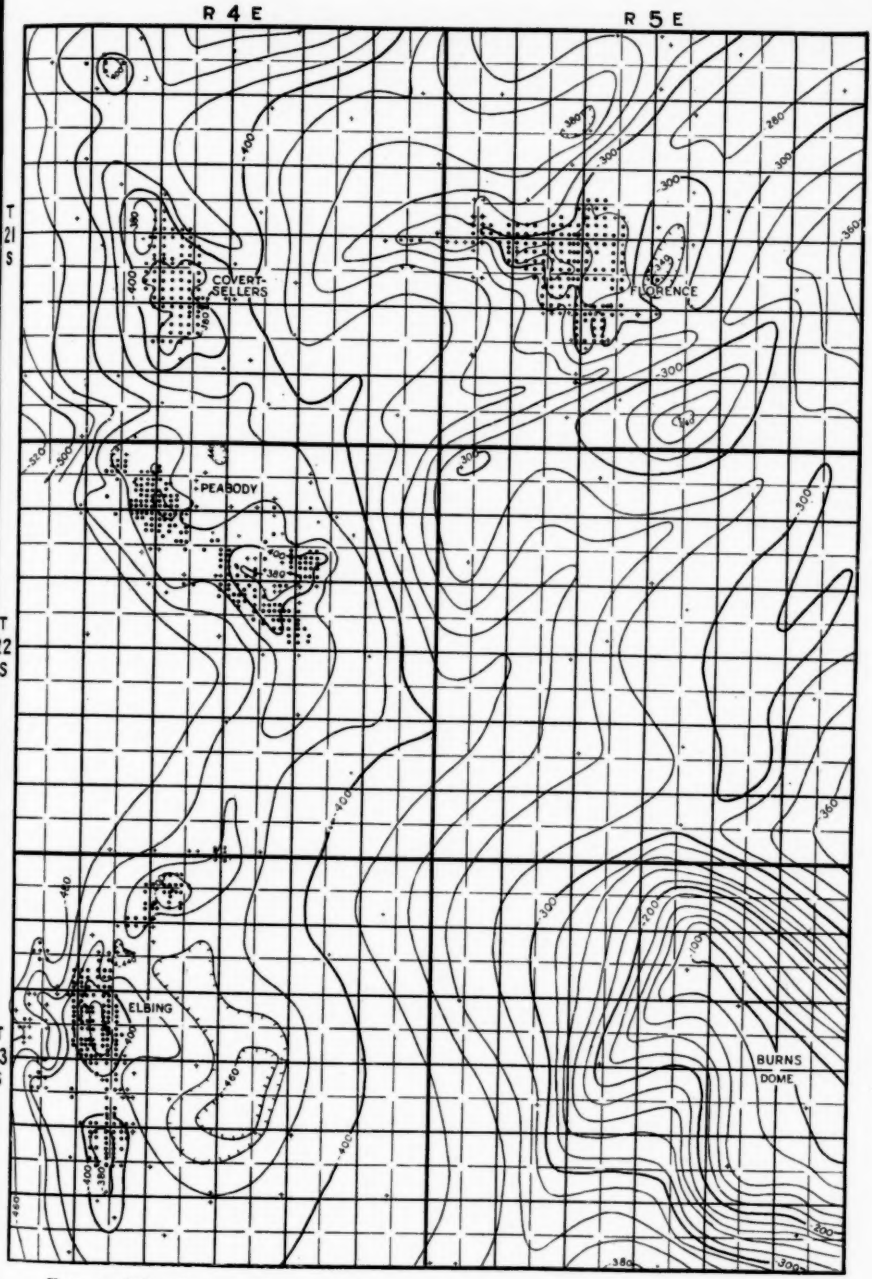

FIG. 3.—Subsurface structure on the Ordovician producing horizon. Contour interval, 20 ft. Scale, one township approximately 6 miles square.

ments, and that in compacting, not only is it possible that the overlying sediments would be deformed into anticlines over the buried hills, but that such a condition is inevitable.

It is undoubtedly true that no other theory of folding will account for all the features of the folds overlying the Nemaha Mountains and their subsidiary hills.

FAULTING

There is no surface faulting in this region. Subsurface faulting is probably confined to the east face of the Nemaha Mountains. In the opinion of the writer, the Nemaha Mountains consist of a long fault scarp extending generally northeast and southwest across the state of Kansas and well into Oklahoma and Nebraska. This scarp has been subject to much erosion, and before it was completely covered by Pennsylvanian sediments it consisted of many peaks and re-entrant valleys such as one might expect under such conditions. This must have been a normal fault with the downthrow to the east, but though normal, the area west of the fault seems to have been uplifted rather than that to the east depressed. This seems to be demonstrated by the fact that east of the fault the complete Kansas section is present, whereas, to the west, one must go a considerable distance before it is found.

RESERVOIR ROCKS

The principal producing horizon in this territory is the erosion surface of the Ordovician. This zone consists of a siliceous limestone which is very porous. In many cases it is directly overlain by a brown shale of a few feet in thickness. Since the drill goes directly from this brown shale into the oil sand, and in most cases finds no hard cap-rock, it is the opinion of the writer that the color of this shale may well be due to the fact that there is oil directly beneath it. The writer does not know whether or not this shale is found where there is no oil.

SOURCE ROCKS

The source rocks seem to be in the Cherokee and Chattanooga shale section which rest unconformably on the producing horizon down the flanks of the anticlines.[1]

RELATION OF ACCUMULATION TO STRUCTURE

In this area the accumulation of oil is very definitely related to structure. Only the anticlines have produced commercial oil and these have done so prolifically. In the opinion of the writer this oil has originated

[1] Henry Ley, "Granite Ridge in Kansas," *ibid.*, Vol. 10 (1926), pp. 95–96.

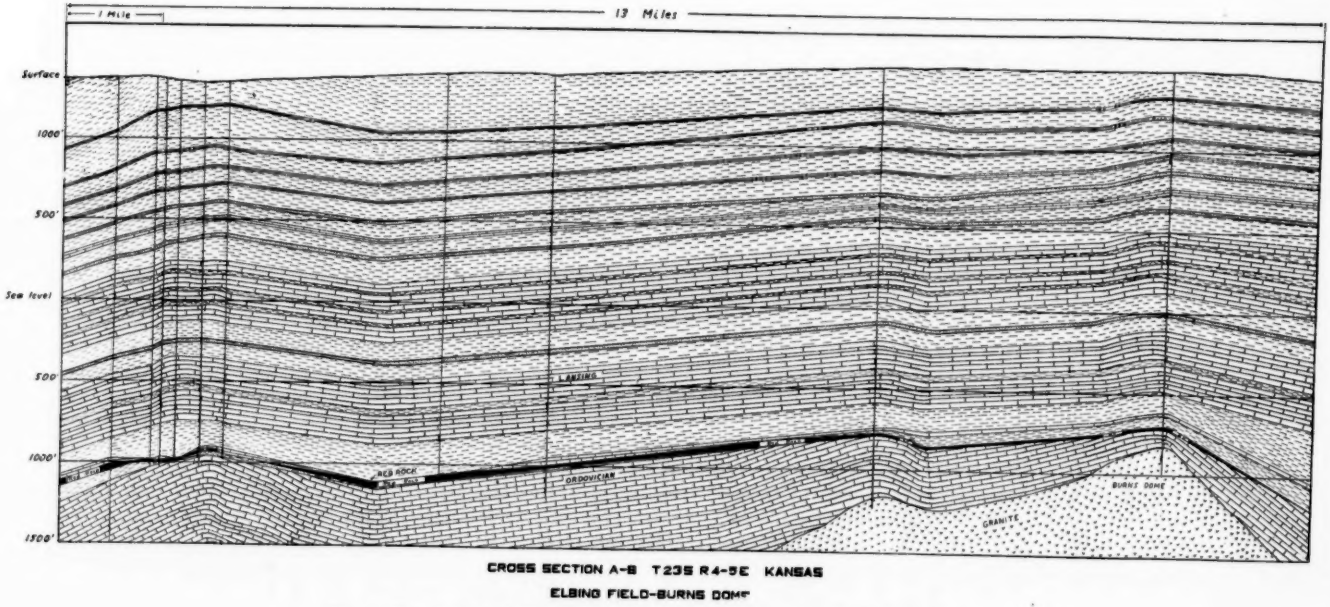

FIG. 4. Cross-section A–B, T. 23 S., R. 4–5 E., Kansas, Elbing Field, Burns Dome

from its source in the Cherokee and Chattanooga shales along the west flank of the ridge and has migrated up the dip to the east until it has been trapped on the tops of these buried Ordovician hills.

To support this statement one must go well into the theories of the migration of oil. Since the organic theory of the origin of oil is generally accepted the writer will make no assertions along this line. Since the Cherokee shales section has been well established in both Oklahoma and Kansas as a source rock of oil, no further attempts will be made to demonstrate these as such in this instance.

Regarding the accumulation of oil there are but four possibilities: It originated in the place from which it is produced; it migrated there either laterally or vertically, or by a combination of both lateral and vertical migrations.

Consider the first possibility, that it originated in its present position. In this area no oil is found beyond a few feet below the top of the pay. The pay is so prolific on the top of the anticlines that it is impossible for organic remains in these few feet of sediments to be so abundant as to account for the oil recovered. Since no metamorphism is present, there is no accounting for the anticlines being more prolific than the synclines, or the tops of the anticlines being more prolific than the flanks.

Considering the third possibility, that the oil migrated vertically, we must presuppose joints or fractures across the bedding planes of the rocks through which the oil may move. Such joints would have been the result of stresses and strains during folding. In this instance, the higher beds being deformed by differential settling, there should be a minimum of jointing as compared to anticlines formed by lateral movements. Furthermore, if this vertical migration were downward, the accumulation should take place at the bottom of a porous horizon. If upward, the logical method, it should be at the top of the reservoir. The oil is, of course, at the top of the reservoir rocks. But, if vertical migration were in force, one should find traces of oil in the beds below the pay. No such traces have been found.

As to a combination of lateral and vertical migration in this area, the same objections apply as to purely vertical migration.

The other possibility, lateral migration, is the only one that fits this area. We have known lateral passageways, the bedding planes of the rocks, and the porous erosion surface of the producing horizon. We have known adequate source rocks down the flanks of the anticlines. We have known anticlinal accumulation and no recognized reason for such accumulation on anticlines unless the oil has moved laterally.

In so far as the movement up or down the dip is concerned, the writer offers the following data: The more prolific production in this area lies either on the top or along the west flank of the anticlines. The production extends farther down the dip on the west flank than on the east. East of the Elbing field is the Burns dome. This dome is much higher than the Elbing anticline. Over most of it the Cherokee has never been deposited. Between the field and this dome there is a very limited quantity of possible source rocks. West of all these fields there are untold areas of source rocks.

Taking all the foregoing facts into consideration, the writer believes himself justified in expressing the opinion that in this area the oil has originated in the Cherokee and Chattanooga shales, along the western flanks of these buried hills, that it has migrated laterally through these shales, from the west and up the dip until it has come in contact with the erosion surface of these buried hills. Thence it has moved toward the tops of these anticlines until it was trapped.

As to the distance covered in this migration, it is impossible to secure any facts on which to base any conclusion. In the opinion of the writer, if it be admitted that oil will travel any distance whatsoever, then no limit can be placed on the distance of its migration, provided that there be sufficient means for moving it and nothing to obstruct its passage.

OIL AND GAS

The oil in these fields averages about 32° Baumé. There is no gas produced in the Ordovician producing zone. Small quantities of gas have been found in the Pennsylvanian series, but very little is of commercial value. In a few places oil has been produced in commercial quantities from sands in the Pennsylvanian, but this production is so limited that it will be given little attention in this report.

A few wells in this territory have produced naturally from the Ordovician. The vast majority had to be pumped. Those that produced naturally did so with a uniform flow, with no bursts, and with but little daily variation. The pressure behind this flow was purely hydrostatic.

As the fields became more developed, the water problems became more acute. The water line not only encroached more and more toward the tops of the anticlines, but each well produced an increasing quantity of water. Many methods were devised to handle this tremendous quantity of fluid. The problem was really acute. As there was but a small percentage of oil in the fluid lifted, the lifting cost had to be at a minimum. The combination of very long-stroke pumps, some of them with a roller drum instead of a beam, and 3-inch tubing, seemed to give the most satisfaction.

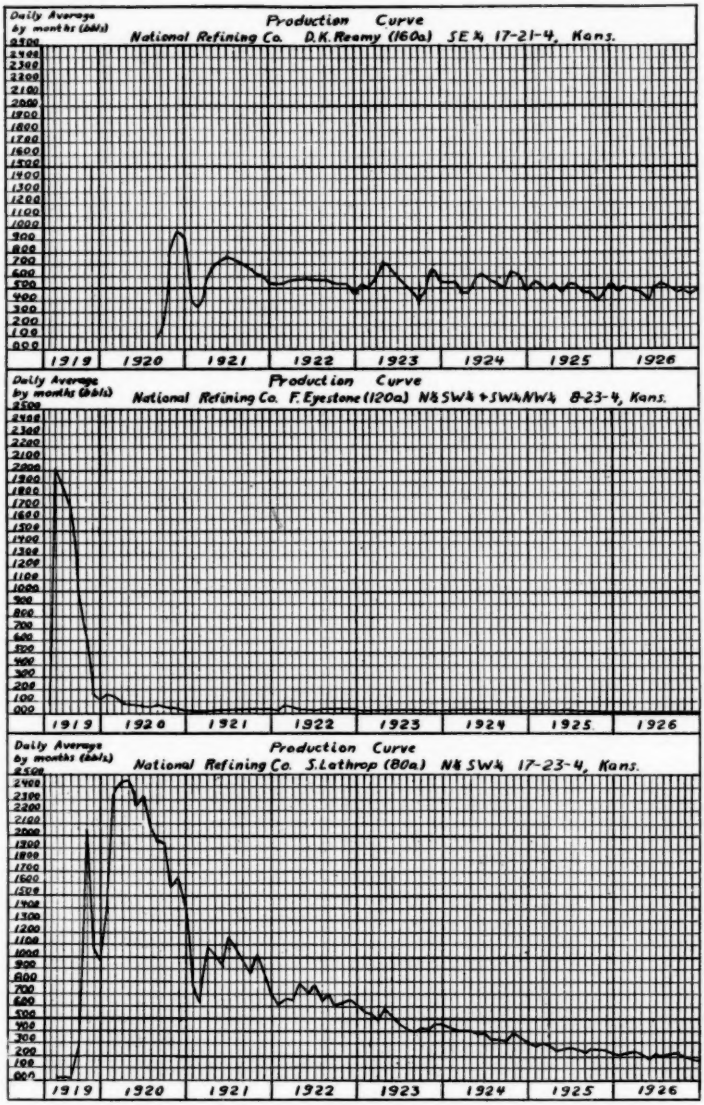

FIG. 5.—Production curves

Abandonment, as in other fields, occurred when the cost of production approached the value of the recovered product. Though but seven or eight years old, most of the wells in this area have been abandoned. The present production of the entire area is small. This does not mean that these were unprofitable fields. On the contrary, they were intensely profitable. The tremendous flush production paid for the development not long after completion, leaving the later production as clear profit.

Another feature of this production is that owing to the porosity of the sand the encroaching waters sweep most of the oil before them, thus attaining an ultimate recovery much more closely approximating 100 per cent of the accumulated oil than is possible in any sand field.

PRODUCTION FIGURES

Owing to the fact that these fields were brought in several years ago, and that production figures of that age are difficult to obtain, the writer has had considerable difficulty in obtaining any accurate production figures. However, he submits curves of three leases in this territory which are based on accurate records (Fig. 5). Of these three curves submitted there is such a lack of similarity that no effort is made to suggest that any one of them is a type curve of this area.

SUMMARY

In this report the following conclusions have been reached:

The principal producing horizon is the unconformable contact between the Ordovician and overlying sediments.

The surface folds, with minor exceptions, consistently overlie the Ordovician buried hills.

The surface folds are due to differential settling over these buried hills.

The petroleum accumulation has been due to lateral migration.

The porosity of the reservoir rock and the encroaching waters have caused an extremely high percentage of ultimate recovery.

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THE TURKEY MOUNTAIN LIME POOLS, OKLAHOMA[1]

PAUL RUEDEMANN AND H. E. REDMON[2]
Tulsa, Oklahoma

ABSTRACT

The "Turkey Mountain lime" consists of three members as distinguished by color: an upper brown, a middle gray, and a lower white. The three together average about 60 feet in thickness. Because of the unconformity at the top the whole section is seldom found.

Production from this lime declines rapidly in the initial stage, but generally declines slowly in the settled stage. The ultimate yield is about 8,000 barrels per acre. Production conforms to geological structure and there is no record of synclinal producing wells. The eroded Turkey Mountain surface is undoubtedly the origin of many "Wilcox" structures. The source of the oil is probably from the black and green shales at the bottom of the Hominy (Burgen) sand or from the "Turkey Mountain lime" itself.

The producing area from which this horizon derived its name was discovered in 1922 on the south slope of a ridge near Tulsa, Oklahoma, known as Turkey Mountain. As the operators in that pool had no geological departments, no reliable records or complete set of sand samples were kept. Since that time any production found in the same general position with reference to the "Mississippi lime" is referred to as the Turkey Mountain "sand."

The "Turkey Mountain lime" was laid down in late Arbuckle or early Ordovician time. The accompanying table shows its relationship with other horizons below the "Mississippi lime" in northeast and east-central Oklahoma.

The best Turkey Mountain lime pools have been found where the "Wilcox" sand is non-existent. In Wagoner County there are several good gas pools, and farther northwest, in Tulsa and Osage counties, excellent oil pools are found. The most prominent of these are the Turkey Mountain, Country Club, Bruner, Inscho, Oakhurst, Fisher, Bowden, and the new Glidden pool near Sand Springs. All of these pools are within a radius of 60 miles from Tulsa.

Some geologists classify the Hominy production of the southwestern part of Osage County as "Turkey Mountain." This correlation is probably correct. As a rule the pools are not more than 40 acres in extent, and

[1] Read before the Association at the Tulsa meeting, March 26, 1927.

[2] Geologists, Thompson & Black, Inc., Atlas Life Building.

the bulk of the production is obtained from one or two wells. The initial production on the largest wells may be as much as 7,000 barrels a day, but it declines rapidly, and may continue to do so until water appears. On the other hand, the wells may remain at the small pumper stage for several years. There is considerable variation between pools in the rate of decline after the initial stage is past. The ultimate production averages about 8,000 barrels an acre.

The horizon referred to as Turkey Mountain "sand" is a lime body found in its full extent to be about 100 feet thick. It is not a siliceous, but

TABLE I

Oil-Field Name	Formation Equivalent	Age
"Mississippi lime"	Mississippian limestone	Mississippian
Black shale	Chattanooga shale	Devonian
		Unconformity
"Meisener" sand	Sycamore sandstone	Siluro-Devonian
"Hunton lime"	Hunton formation	
Sylvan shale	Sylvan shale	Upper Ordovician
Viola lime	Viola limestone	Middle Ordovician
"White lime"		Unconformity
Post-"Wilcox"	Upper and Middle Simpson formation	Ordovician
"Wilcox" sand		
Green Series or "Irish" sand	Tyner	
"Hominy" sand	Burgen	Unconformity
"Turkey Mountain lime"	Eroded surface of late Arbuckle	Cambro-Ordovician
"Stray sand" (lenticular)		
"Siliceous lime"	Arbuckle limestone	

* From Luther White, *Okla. Geol. Survey Bull. 40-B*, with additions by the authors.

a dolomitic, lime. Luther White in his publication[1] on the post-"Wilcox" formation of northeastern Oklahoma has mentioned this distinction. Dr. Rudolf Ruedemann[2] places this lime as late Beekmantown or Chazy Lowville (Ordovician) in age. How far this lime body extends has not been determined but it might at one time have been comparable to other major limestone formations in Oklahoma. The largest production generally occurs where a brown member exists. This brown lime is easily recognized from drill cuttings, as it drills into small oval pieces resembling wheat. Underneath the brown lime lies a gray and in places cherty lime. In places this becomes slightly shaly or sandy and may carry oil. Below the gray lime occurs a white lime series which is very soft and might easily be taken

[1] "Subsurface Distribution and Correlation of the Pre-Chattanooga Series of Northeastern Oklahoma," *Okla. Geol. Survey, Bull. No. 40-B* (1926), p. 12.

[2] Personal communication.

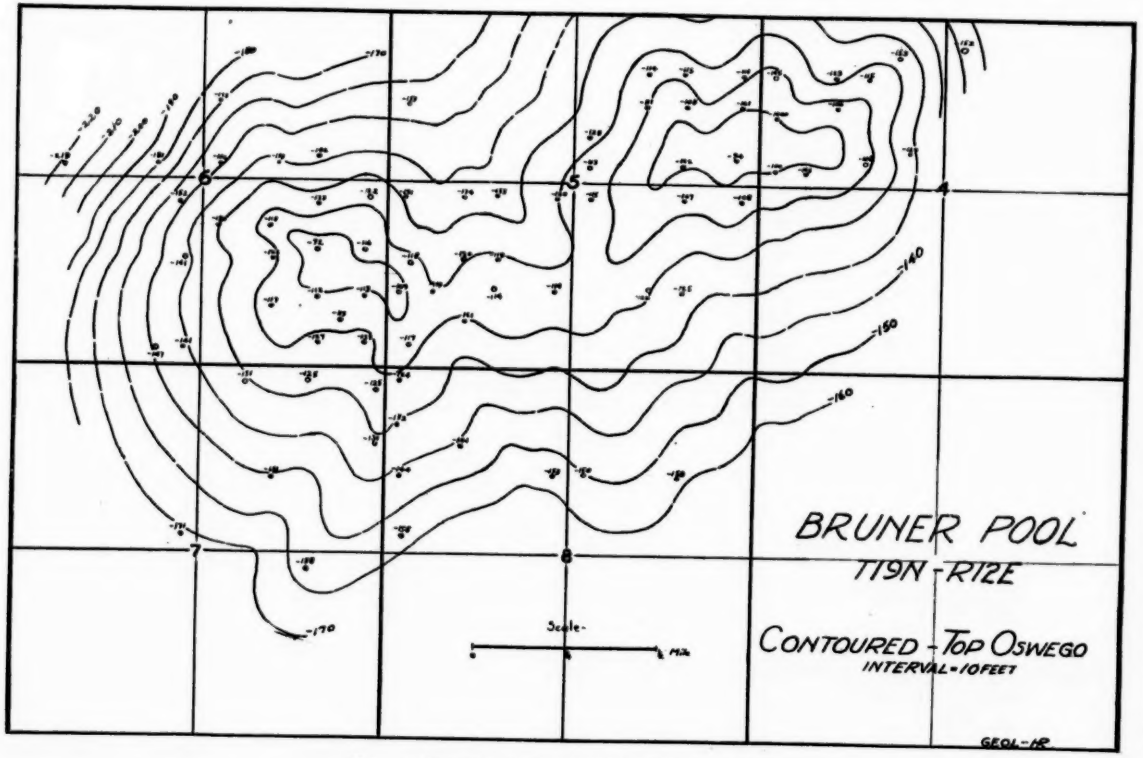


FIG. 1.—Bruner Pool, contoured top of Oswego lime

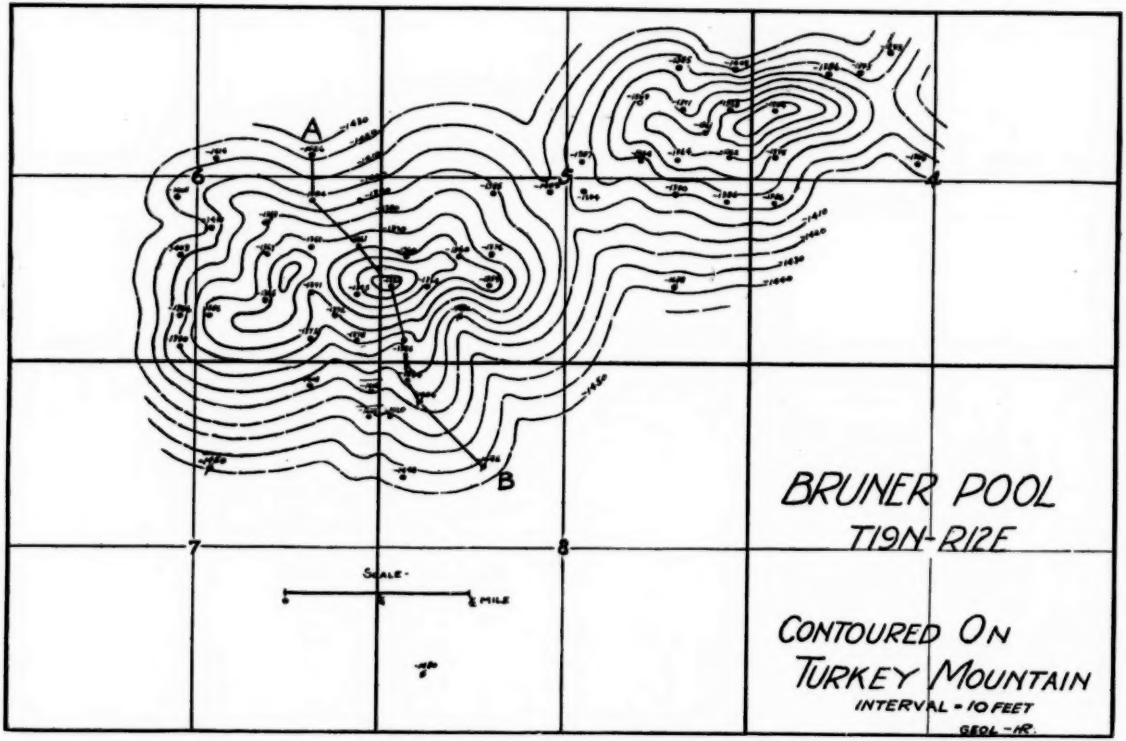


FIG. 2.—Bruner pool, contoured top of Turkey Mountain lime

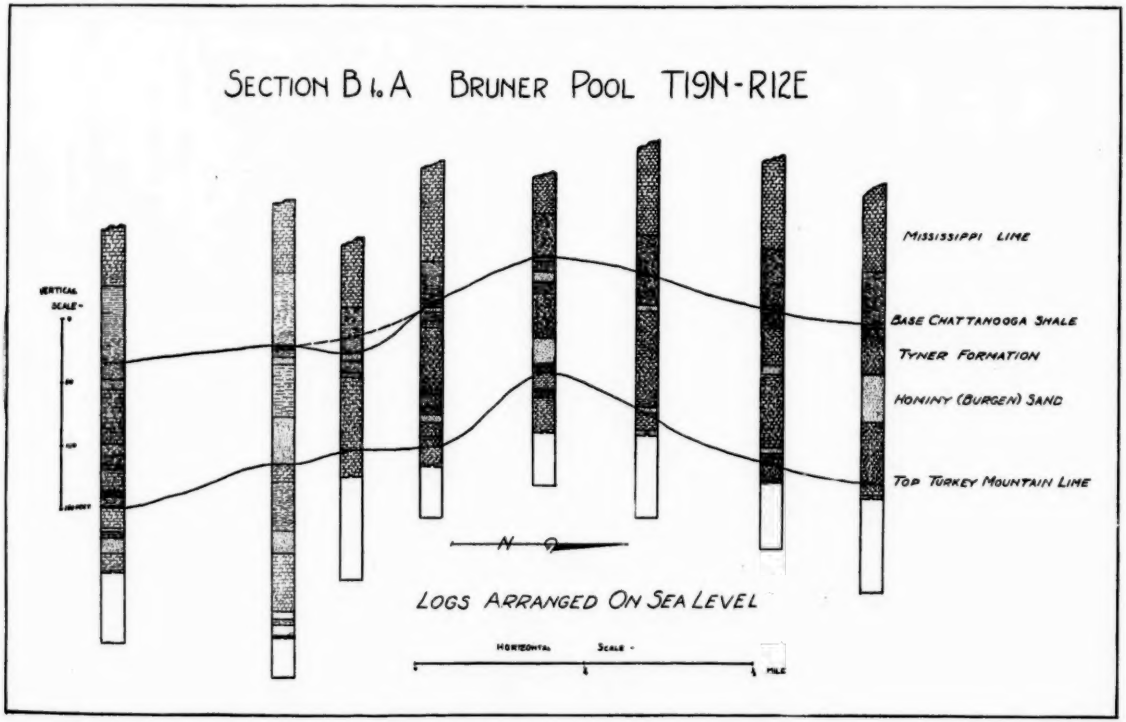


FIG. 3.—Section showing thinning of interval on apex of anticline

for the Viola limestone. The cuttings from this lime resemble corn flakes. At the bottom of the "White lime" is found a thin lenticular sand, below which is the "Siliceous lime." This thin sand body carries water, and at

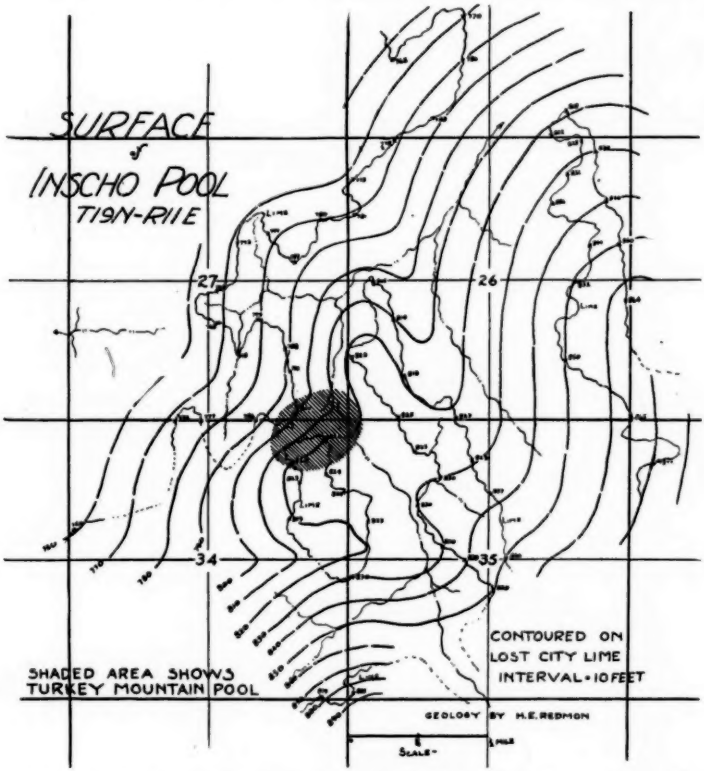


FIG. 4.—Inscho pool, showing relation of Turkey Mountain pool to surface terrace.

one location carried a good show of live oil, but the test in this case was not favorably located on structure. Commercial pools may sometime be developed in this horizon. Some apparent sand bodies found throughout the Turkey Mountain limestones are in reality pure calcite, which drills up much like sandstone. An interval of 200 feet below the base of the "Wilcox," if present, and otherwise the base of the Chattanooga, will in most places reach the Turkey Mountain.

The top of the "Turkey Mountain lime" is an unconformable surface. The unconformity occurs between it and the later formations, but it is apparently conformable with the "Siliceous lime." This accounts for the

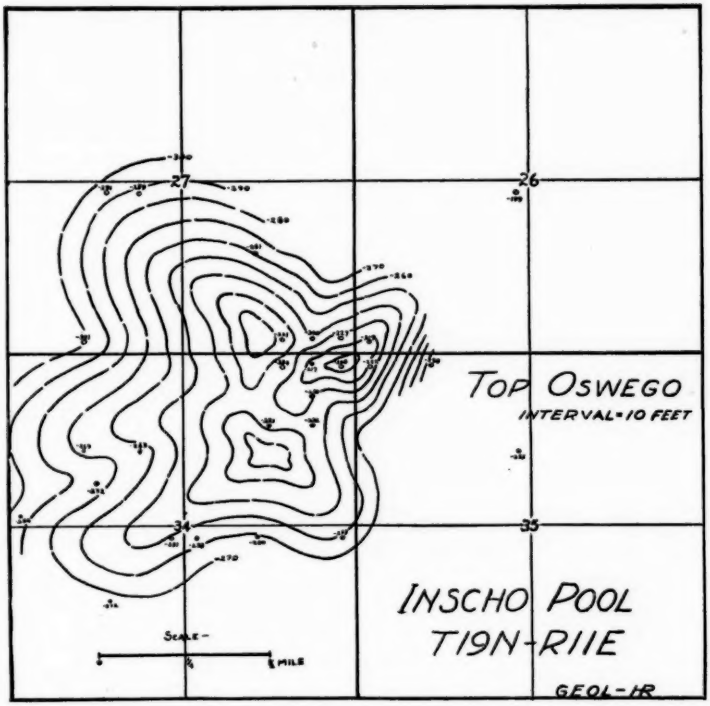


FIG. 5.—Inscho pool, contoured top of Oswego lime

irregularity of the production, and in places the presence of gushers on the flanks and small producers or dry holes on the tops of the anticlines. It also accounts for the complete or partial absence of the lime in many places. Contrary to what one would expect, this lime seems to be thicker on the anticlines than in the synclines, but this tendency cannot be proved on the present meager information.

The Bruner pool in T. 19 N., R. 12 E., six miles west of Tulsa on the Sand Springs road, and the Inscho pool in T. 19 N., R. 11 E., are herein described as type pools. In the Bruner pool there is a closed anticline on the

Oswego lime. There being little or no "Wilcox" sand present, the bottom of the Chattanooga shale is used as the next marker. The apex of the anticline in this horizon is about one-quarter mile southeast and the rate of dip is about twice that of the Oswego structure. The contours on top of the

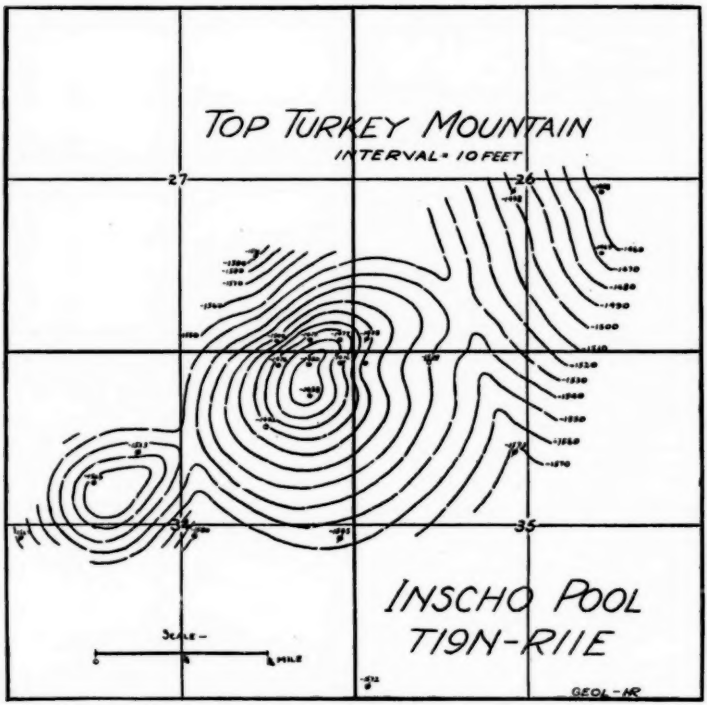


FIG. 6.—Inscho pool, contoured top of Turkey Mountain lime

"Turkey Mountain lime" show the apex in the same relative position as found at the bottom of the Chattanooga shale, but the dip is three times the rate of that found in the Oswego structure. This indicates considerable thinning of interval on the top of the structure between the Chattanooga shale and the top of the "Turkey Mountain lime," due to erosion and compaction.

Because of the erosion of the "Turkey Mountain lime," the true top of the original Bruner anticline may have been one-quarter mile farther

south than the present dome shows, as indicated by the accompanying sketch (Fig. 7). In this pool the wells on the north flank found the brown lime which is the upper member of the "Turkey Mountain lime"series; whereas, the wells on the south flank passed from the Hominy sand into the gray lime member below the brown lime.

In the Inscho pool the "Turkey Mountain lime" fold is centered under the Oswego high, and the dip, as in the Bruner pool, has trebled in rate in the deeper formation.

In Turkey Mountain pools, in general, the best production seems to occur where the brown lime member is present. This is not always essential. The original Turkey Mountain pool itself is producing from the gray lime member, according to supposedly reliable drill cuttings. In a small pool about 6 miles east of the original Turkey Mountain field, the brown and gray lime members are both absent and production on top of this dome was found in the lower part of the "White lime" member, although a test less than a quarter-mile southwest found no part of the "Turkey Mountain lime" series present. Near Haskell a gas pool occurs in the white series. If any of the lime members are sufficiently porous, commercial production is likely to be found, even though the main part of this series might have been eroded. Turkey Mountain production exists only on closed anticlines, but only a few such structures contain commercial production. Water of commercial value occurs in this formation. The radium water springs of the Claremore district are Turkey Mountain. The Sand Springs Home saves all the salt water from the Bruner pool and has built up a profitable industry for the extraction of salts.

As stated previously the "Turkey Mountain lime" pools to date have been found only where productive "Wilcox" sand does not exist. This may be a coincidence, as in the areas where "Wilcox" sand is productive there are not enough tests favorably located to eliminate the "Turkey Mountain lime" as a potential producing horizon under existing "Wilcox" pools. "Turkey Mountain lime" production probably covers a far greater area than we now anticipate. The source of the oil found in the "Wilcox" sand is generally conceded to be the Chattanooga black shale. It is difficult to conceive of this black shale as being the source bed of Turkey Mountain production, especially where sand bodies capable of making an oil reservoir are found between it and the black shale. It might be assumed that the oil traveled downward through faults or that the oil migrated along the "Turkey Mountain lime" contact from the areas where the black shale lies against the Turkey Mountain formations. This seems improbable, and it is more likely that the source of the oil is in the black and green

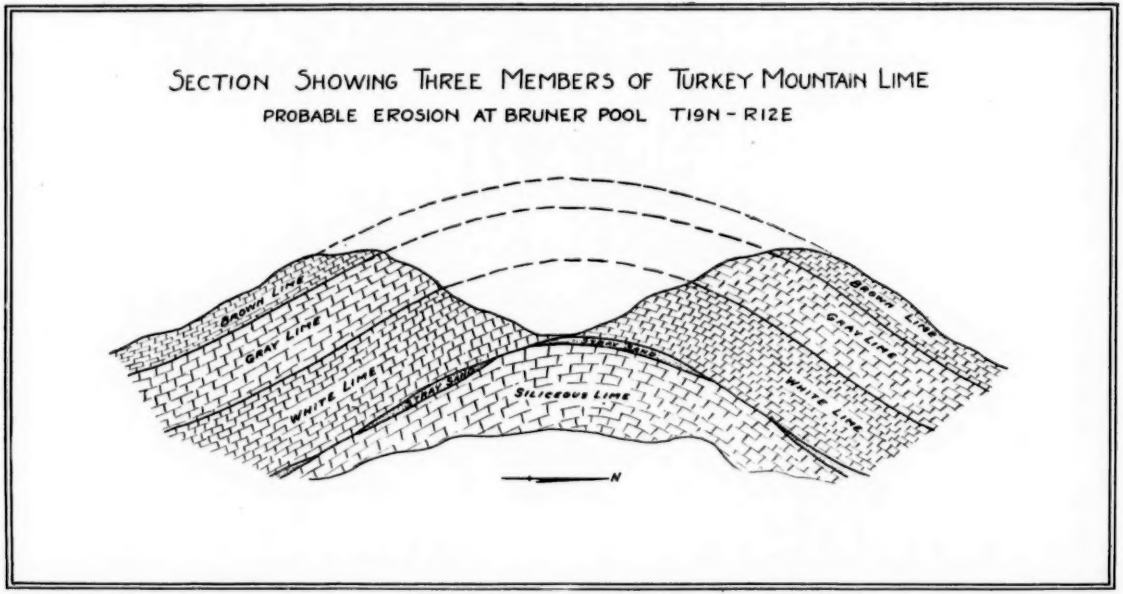


FIG. 7.—Turkey Mountain lime at Bruner pool, showing (*a*) division into three lime members, (*b*) erosion of Turkey Mountain lime. Generalized section, not drawn to scale.

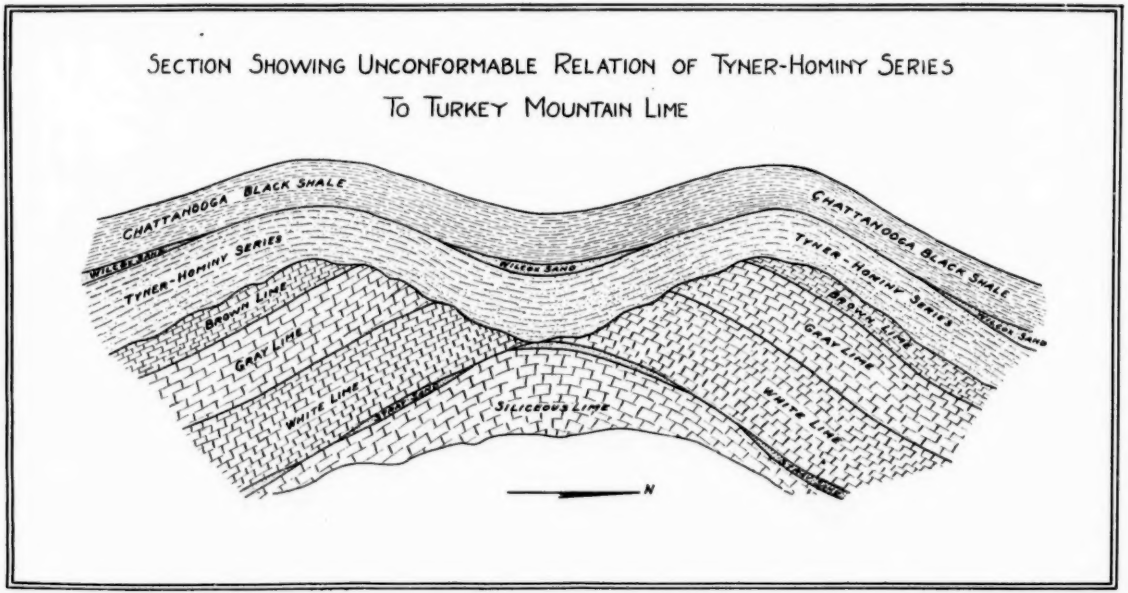


FIG. 8.—Showing the unconformable relation of post-Turkey Mountain to Turkey Mountain (Bruner pool is producing from the erosional peak at the right). Generalized section, not drawn to scale.

shales frequently found at the bottom of the Hominy sand, or from the "Turkey Mountain lime" itself.

DISCUSSION

LUTHER WHITE: The Hominy sand production of the Osage should not be correlated as coming from this sand, but from the Turkey Mountain lime. It is erroneously called "Hominy sand" because the drillers like to associate oil with sand. I would like to ask whether the Turkey Mountain is of lower Simpson or late Arbuckle?

PAUL RUEDEMANN: It is most likely late Arbuckle and the unconformity occurs between it and the Simpson.

L. B. SNIDER: Figure 8 of Mr. Ruedemann's paper pictures a condition which seems highly improbable.

An anticline in the "Siliceous lime" and "Turkey Mountain lime" is pictured as eroded to the "Siliceous lime," then covered with Tyner and Chattanooga.

Folding in the Chattanooga and Tyner is parallel to the erosion surface.

The normal tendency would be for the Tyner and Chattanooga to fill in the erosion valley, until the beds were relatively flat, rather than synclinal.

Compaction might cause a slight syncline in the Tyner and Chattanooga, but later folding, which certainly occurred, would produce an anticline in the Tyner and Chattanooga.

It is very unlikely that erosion on minor structural features ever shows as close a relation as indicated in the figure.

PAUL RUEDEMANN: Figure 8 has been greatly exaggerated, primarily in the vertical section, to bring out a condition that is likely to occur in this portion of the Mid-Continent field. On the anticline in question the south dip was less than the interval of the "Turkey Mountain lime" that was missing. The top member of the lime was present on the whole north flank. A small structure near Broken Arrow has only as much closure as there is erosion of the "Turkey Mountain lime." It has also been noticed that a high percentage of synclinal tests get little or no "Turkey Mountain lime," but anticlinal tests are more likely to get a full section thereof. These two facts are merely general observations which the authors hope in time to prove. The assumption of formation of structure by folding in the region of Tulsa so far lacks proof. Our general knowledge points to the formation of these structures by deposition and compaction on erosional hills. These hills may have their origin in the granite basement or on the unconformable surface of the Arbuckle–Turkey Mountain limes.

STRUCTURAL CONDITIONS IN PORTIONS OF EASTERN OHIO[1]

KENNETH COTTINGHAM[2]
Columbus, Ohio

ABSTRACT

Regional contour maps are shown on the surface of the Trenton in the western half of Ohio, and on the Berea and Clinton in eastern Ohio. The major structural features are the Cincinnati arch, as expressed by the Trenton, and less conspicuously, the syncline (Parkersburg) and adjacent Cambridge anticline as shown by the Berea in eastern Ohio. Structure contour maps are given for four areas in eastern Ohio. These are for the Berea in southeastern Meigs County and northeastern Muskingum County, for the Berea and shallow sands in the junction of Guernsey, Noble, Belmont, and Monroe counties, and for the Clinton sand in the Homer field of Knox and Licking counties.

The majority of the producing fields of eastern Ohio display some relationship to structure, although the relationship is ideal in but few cases. Structural highs are generally barren, the production lying on the flanks of anticlines or even in the upper ends of synclinal embayments. There is, then, a structural relationship, though not in the stricter sense in which the anticlinal theory was once applied. Most of the oil and gas accumulations are associated with some kind of structural irregularity. As a rule, there is a definite parallelism between the trend of production and the strike of the rocks. In a few places accumulation appears to be entirely a matter of lithology, notably in the Cow Run sand of the Chester Hill field, in Athens, Morgan, and Washington counties. In general, three factors appear to govern accumulation: local structure, water content and energy of movement in the sand, and the porosity of the sand. Since local structure exerts some influence on both water content and artesian conditions in a given sand, structure is regarded by the writer as the dominant factor.

These remarks as to accumulation apply to the Berea and higher sands. The Clinton has long been known as a sand practically devoid of water, although this classification can be accepted only as relative. Because of the lack of reliable key beds, the rapid divergence from surface beds, and the lenticularity of the Clinton, one cannot be sure of structure as mapped for the Clinton. Clinton production appears to be along a transition zone where the sand thins and is replaced to the west by shales.

GENERAL GEOLOGY OF OHIO

The outcropping formations of Ohio range from the Trenton of the Ordovician to the Greene formation of the Permian. The general areal geology of the state is illustrated in Figure 1. The dominant structure is the Cincinnati anticline, which forks in southwestern Ohio, one prong trending northwest through Franklin, Henry, and Howard counties, Indiana, the other extending north by east through Logan, Hancock, and

[1] Presented before the Association at the Tulsa meeting, March 26, 1927.
Manuscript received by the editor June 13, 1927.

[2] Geologist, Ohio Fuel Gas Company, 99 North Front Street.

Wood counties, Ohio. Figure 2 shows this fold in Ohio and the productive Trenton area. No production of consequence has been discovered in the Trenton in Ohio outside the shaded area.

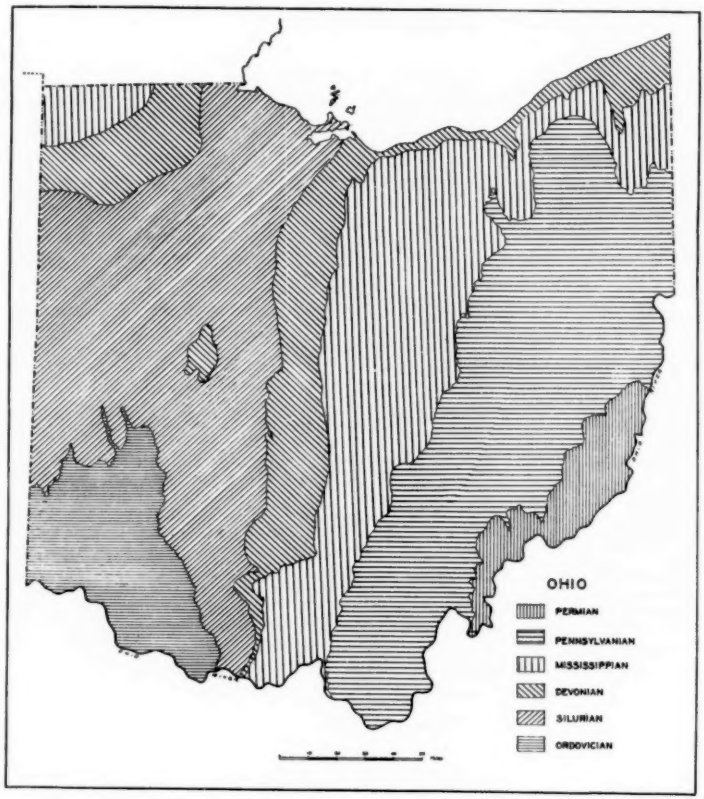


FIG. 1

The general structural conditions of eastern Ohio are illustrated by the contour map of the Berea sand (Fig. 3). The Berea lies just above the base of the Mississippian series, and has an average thickness in the wells of eastern Ohio of 20 feet. The maximum thickness known to the writer is 150 feet, reported in a well drilled some years ago at Youngstown, Ma-

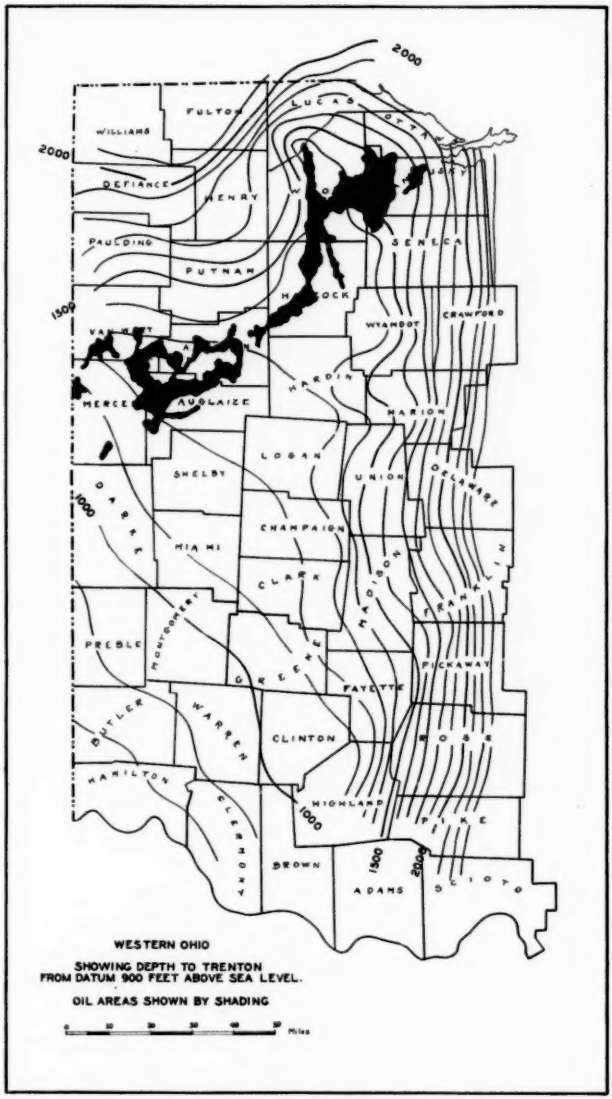

2000
2000
1500
1000
1000
1500
2000
WILLIAMS
FULTON
LUCAS
DEFIANCE
HENRY
PAULDING
PUTNAM
SENECA
WYANDOT
CRAWFORD
HARDIN
MARION
AUGLAIZE
LOGAN
UNION
DELAWARE
SHELBY
CHAMPAIGN
MIAMI
CLARK
MADISON
FRANKLIN
PREBLE
MONTGOMERY
GREENE
PICKAWAY
FAYETTE
BUTLER
WARREN
CLINTON
ROSS
HAMILTON
CLERMONT
HIGHLAND
PIKE
BROWN
ADAMS
SCIOTO
WESTERN OHIO
SHOWING DEPTH TO TRENTON
FROM DATUM 900 FEET ABOVE SEA LEVEL.
OIL AREAS SHOWN BY SHADING

FIG. 2

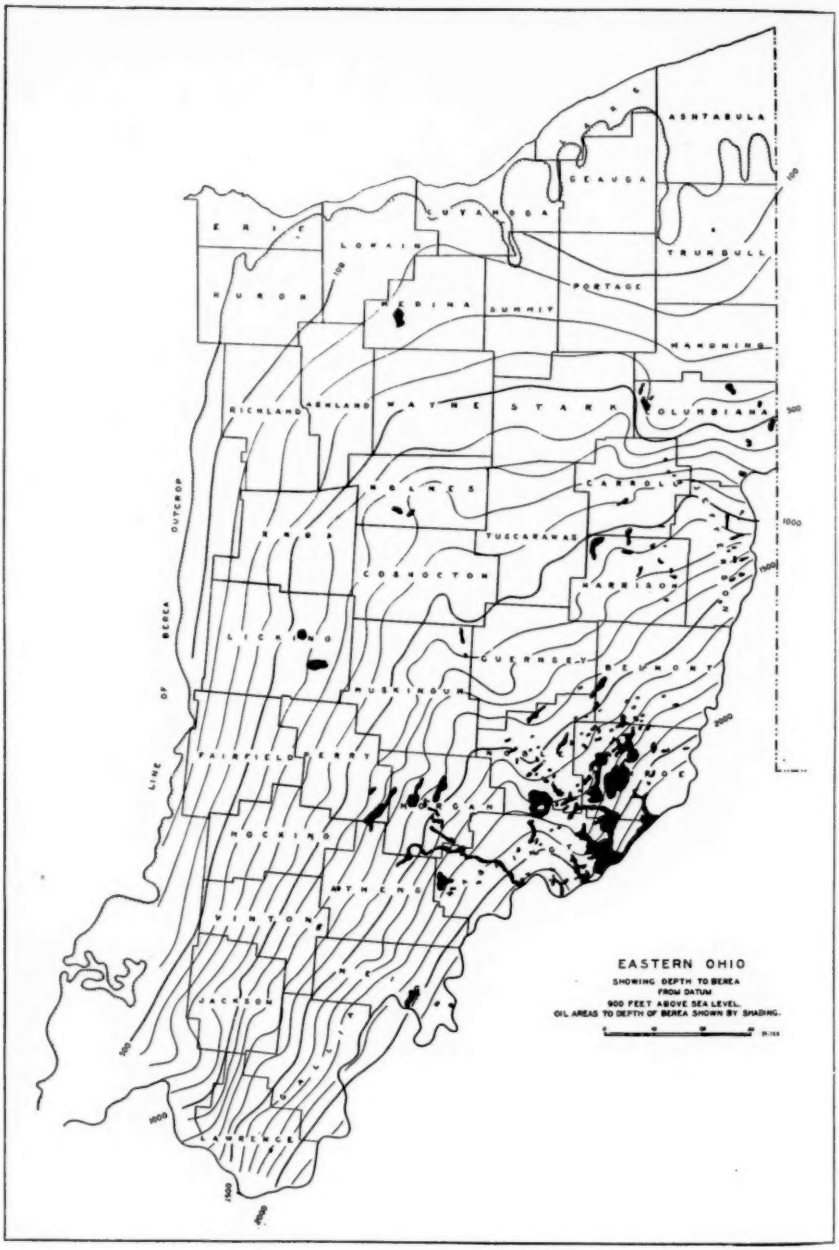

ASHTABULA
GEAUGA
CUYAHOGA
TRUMBULL
ERIE
LORAIN
PORTAGE
HURON
MEDINA
SUMMIT
MAHONING
RICHLAND
ASHLAND
WAYNE
STARK
COLUMBIANA
HOLMES
CARROLL
TUSCARAWAS
KNOX
COSHOCTON
HARRISON
LICKING
GUERNSEY
BELMONT
MUSKINGUM
FAIRFIELD
PERRY
MORGAN
NOBLE
HOCKING
MONROE
WASHINGTON
VINTON
JACKSON
MEIGS
GALLIA
LAWRENCE
OUTCROP OF BEREA
LINE
500
1000
1500
2000
EASTERN OHIO
SHOWING DEPTH TO BEREA
FROM DATUM
900 FEET ABOVE SEA LEVEL.
OIL AREAS TO DEPTH OF BEREA SHOWN BY SHADING.

FIG. 3

honing County. The most conspicuous structural feature of eastern Ohio is the syncline extending from Washington County west of north into eastern Muskingum, thence north to western Cuyahoga County. The narrow, sinuous pool (Fig. 3), running from northern Athens County to the

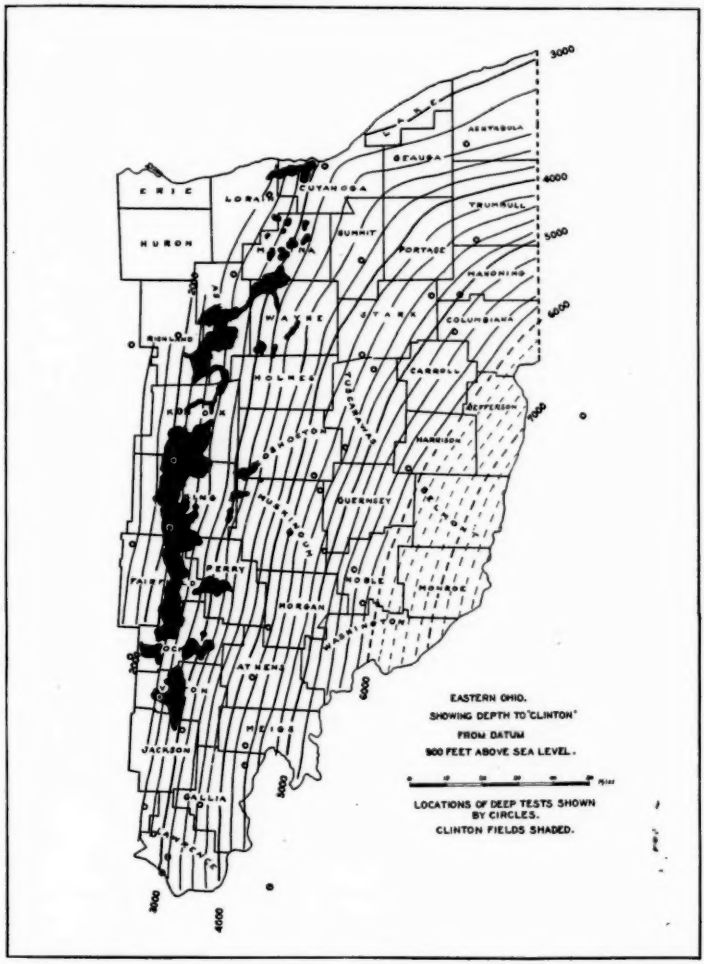


FIG. 4

Ohio River in south-central Washington County, is in the First Cow Run sand. The accumulation in this pool is in a coarse, conglomeratic sand probably representing a buried stream channel.

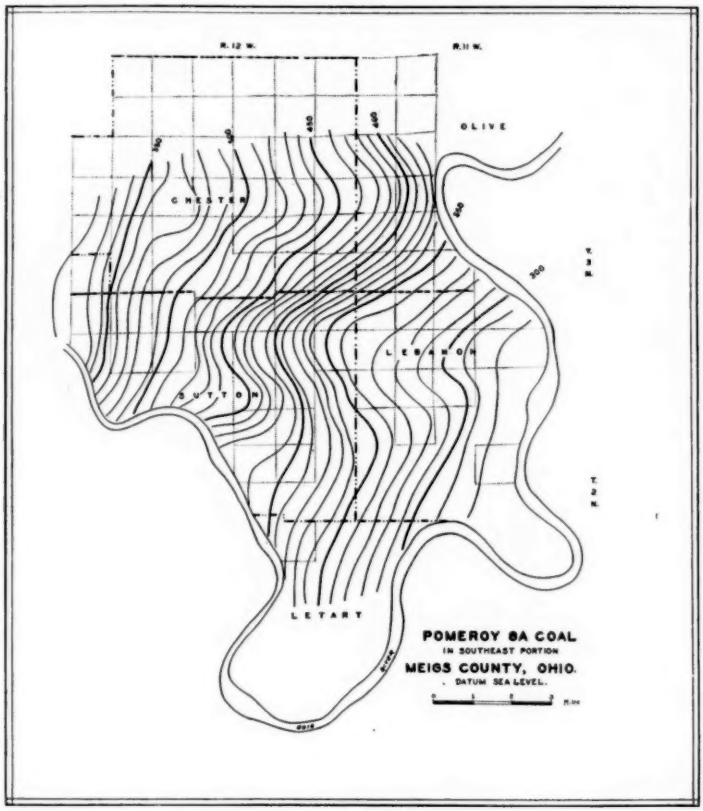


FIG. 5

Reference to Figure 4 will show that the structural features of the Berea are almost effaced in the Clinton, due to the eastward expansion of the Devonian shales and Devonian and Silurian limestones.[1] The Berea-Clinton interval in central Ohio is 1,400 feet. In eastern Monroe County it has increased to probably 5,400 feet.

[1] Cottingham, *National Petrol. News* (August 11, 1926), p. 45.

SOUTHEASTERN MEIGS COUNTY

The attitude of the Pomeroy (8*a*) coal in Chester, Olive, Sutton, and Lebanon townships is shown in Figure 5. The Pomeroy coal, lying 30 feet higher than the Pittsburgh coal (the latter is absent throughout the area), is mined in the western part of Chester and Sutton townships. A composite section for this region from the Pomeroy coal to the Berea is shown in Figure 6.

The structure of the Berea sand is shown in Figure 7. Allowing for the fact that the contour interval is different in the two maps, being 10 feet for the Pomeroy coal and 20 feet for the Berea, it will be noticed that the Berea structure is somewhat different from the surface structure and more moderate. Because of the eastward expansion of intervals, all minor structures of eastern Ohio moderate with depth. In the area mapped here, the interval from the Pomeroy coal to the Berea ranges from 1,530 to 1,700 feet, increasing in general southeastward. The divergence, however, is not regular. There is a notable increase in eastern Chester Township. The consequent thickening of the vertical section occurs in the sandstones between the Sharon coal and the Maxville limestone.

The oil and gas field in Sutton Township was opened in the summer of 1923. The average oil well had an initial yield varying from 15 to 20 barrels. The best gas wells were found on the crest of the nose

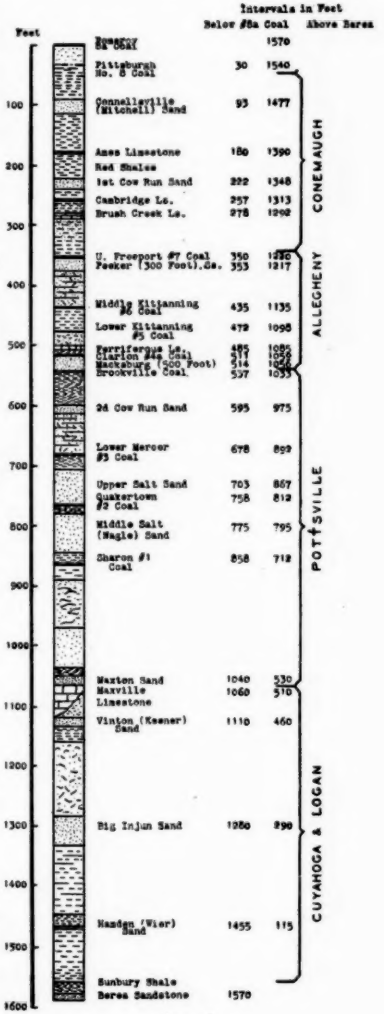


FIG. 6

in Sutton Township (on the map, just below the letter *O* in Sutton). The largest of these had an initial open flow of 5,000,000 cubic feet. The pay is generally in the upper 5 feet of sand.

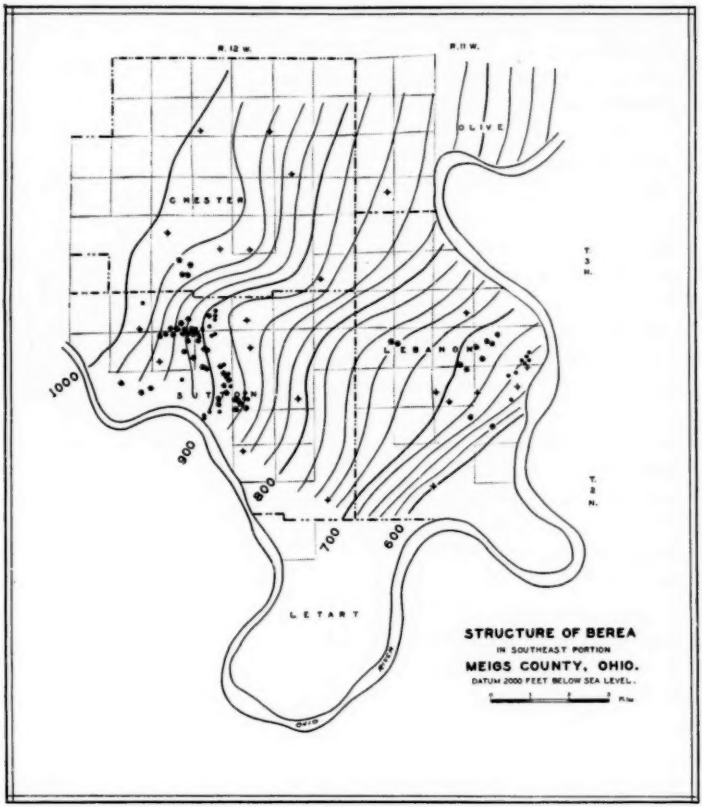


FIG. 7

The pool in Lebanon Township is older. The initial yields of the wells there were less, the initial open flow of the largest gas well being 600,000 cubic feet, and the average 300,000. Several of the dry holes in Lebanon Township showed as little as 2 feet of Berea sand. The sand invariably contains water, generally a few feet below the top.

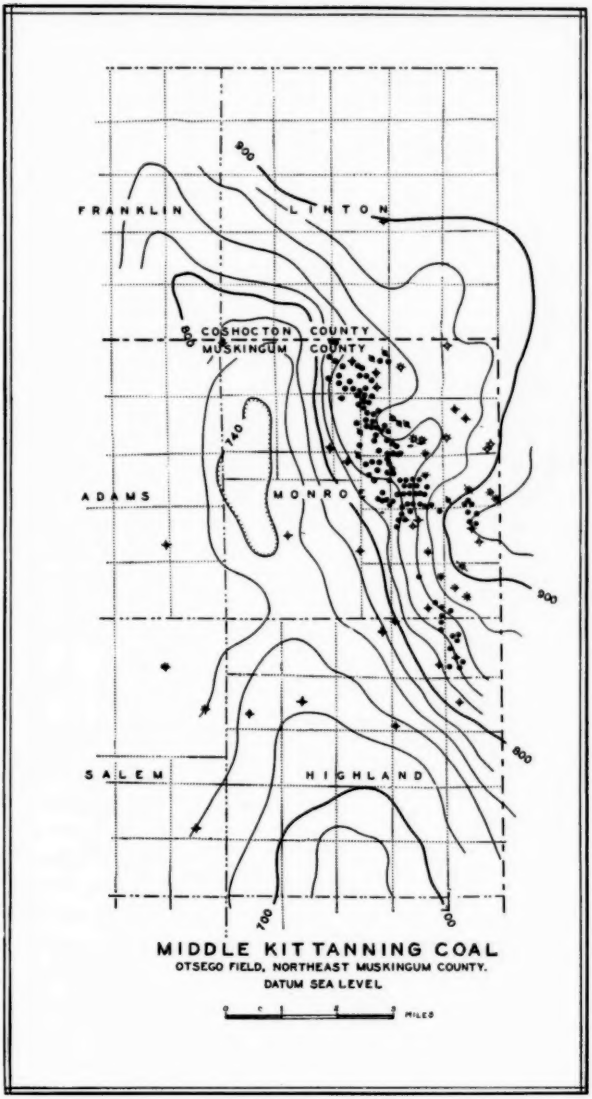

FRANKLIN
LITHTON
COSHOCTON COUNTY
MUSKINGUM COUNTY
ADAMS
MONRO
SALEM
HIGHLAND
900
800
740
700
MIDDLE KITTANNING COAL
OTSEGO FIELD, NORTHEAST MUSKINGUM COUNTY.
DATUM SEA LEVEL
MILES

FIG. 8

NORTHEAST MUSKINGUM COUNTY

The Berea pool in Monroe and Highland townships, Muskingum County (Fig. 8), was opened about 1903. The initial production of the largest wells was 35 barrels; the average was about 10 barrels. The oil is found in the lower part of the Berea, as a rule with more or less salt water. The quantity of salt water increases greatly in the syncline.

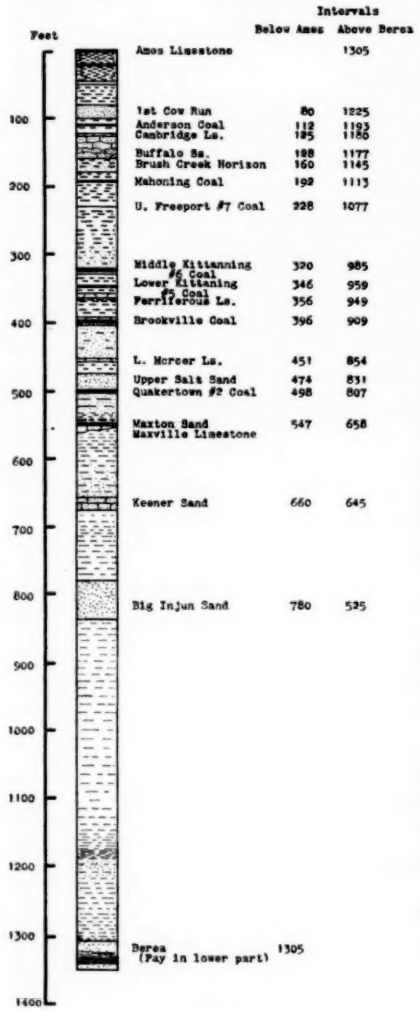


FIG. 9

The interval from the Middle Kittanning coal to the Berea is 985 feet and is constant. Two holes were drilled to the Clinton in Monroe Township, one in the extreme northwestern corner of the township, the other two miles south of the northeast corner and just west of the township line. Both were dry in the Clinton.

This pool lies on the west flank of the Cambridge anticline, as brought out in a general way in the Berea map of eastern Ohio (Fig. 3). The recently discovered Cambridge gas field lies about seven miles southeast. The gas in this latter field is found about 120 feet in the "Niagara" lime, from a sand which many have regarded as correlative with the Oriskany.

The interval from the Berea to the Clinton in the

area mapped ranges from 3,000 feet on the western side to 3,400 feet along the eastern line.

GUERNSEY, NOBLE, BELMONT, AND MONROE COUNTIES

The attitude of the Pittsburgh coal as shown in Figure 10 is taken from *U. S. Geological Survey Bulletin 720.* Although there is some irregu-

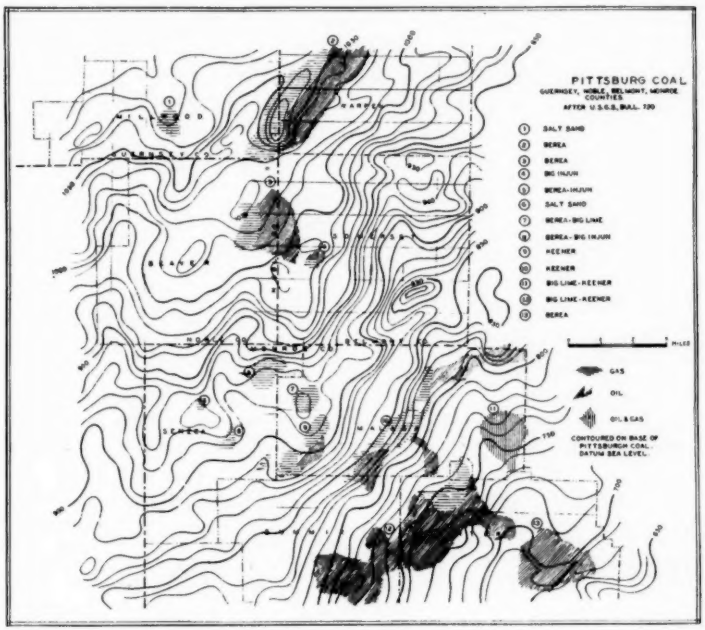


FIG. 10

larity in the Pittsburgh-Berea interval, it is not great enough in the area shown here to make any vital difference between the surface and the Berea structure. The Berea lies about 1,570 feet below the Pittsburgh coal. It has a thickness as little as 3 feet and as great as 40 feet, though the average is about 20 feet. The position of the pay in the Berea differs considerably. In the area shown here, the pay is in the upper part of the sand.

To the depth of the Berea and including it, there are about twelve sands, at least half of them being important as the source of oil or gas. In

several places oil is yielded by sands at points only a few miles east of the outcrop. All of the sands contain water in varying amounts.

The area east of the Cambridge anticline, of which this is a portion, is in general an area of small, irregular folds. The structural arrangement, though not particularly complex, is probably as much so as any part of eastern Ohio. Of the pools shown in the figure, at least eight show a direct relationship to structure.

The first wells drilled in the Barnesville field, (No. 2, Fig. 10), were two gas wells completed about 1890, the first of which had an initial open flow of 750,000 cubic feet and a rock pressure of 640 pounds. The first oil well in this field produced 25 barrels a day. In the Temperanceville field (No. 3), oil was discovered in 1899, and the initial production of the first well was 17 barrels. Both of these fields are Berea. The oil ranges in gravity from 42 degrees in the Temperanceville field to 46 degrees in the Barnesville field.

KNOX AND LICKING COUNTIES

HOMER GAS FIELD

The Homer gas field (Fig. 11) was one of the most prolific fields in Ohio, though well on the way to depletion today. The discovery well was completed in 1900; the initial open flow was slightly more than 1,000,000 cubic feet, and the initial rock pressure 700 or 800 pounds. The average thickness of the Clinton is 18 feet. The largest wells were found in Miller and Morgan townships, the largest having an initial open flow ranging from 8,000,000 to 12,000,000 cubic feet.

Practically the entire area shown on the map yielded Clinton gas, though there were a few dry holes and light producers. The scale of the map makes it impossible to locate all wells. The western limit of Clinton production is indicated by shading, west of which the Clinton sand is replaced by red shales.

Although the Clinton is known as a water-dry sand, that classification is only relative. As Johnson[1] and others have pointed out, the absence of connate water would require a combination of circumstances hardly possible of fulfilment.

EFFECT OF STRUCTURE ON ACCUMULATION

BEREA SAND

Though there are no figures at hand on the matter, the writer would hazard the opinion that 65 per cent of the shallow-sand production in Ohio, including the Berea, has some structural basis. The Clinton is not

[1] *Trans. Amer. Inst. Min. Eng.*, Vol. 51 (1916), p. 587.

included. It is a common occurrence in wells drilled on the crest of domes or other strong types of anticlines to find hard, or broken, or thin sand devoid of gas or oil. In the aggregate, far more oil has been produced from

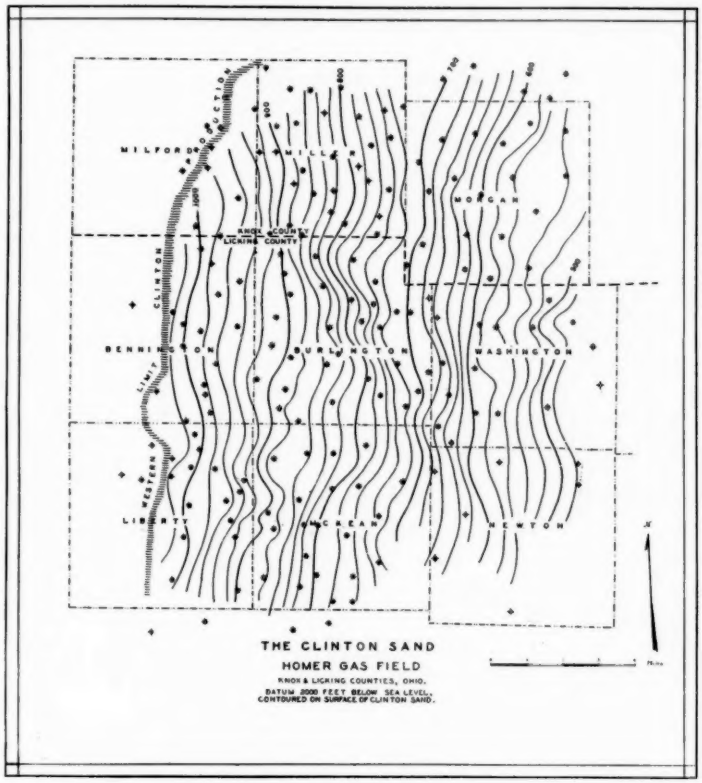


FIG. 11

the Berea on low noses, low on the flanks of folds, and in shallow synclines, than on the crest of domes or folds. Many Berea pools are at the upper end of a structural embayment.[1] Porosity alone can hardly account for these cases because they are too frequently associated with the same type of minor structure. Presumably artesian conditions prevail in the

[1] Condit, *U. S. Geol. Survey Bull. 541—A.*

shallow sands, the water movement being toward the west and northwest or away from the hydraulic head along the Appalachian Plateau. The hydraulic gradient is low, and many of the sands are persistently fine grained, as a result of which water movement is slow. It would seem possible that disseminated oil is carried by circulating water to a point where the velocity of movement is reduced.[1] The fact that so many pools are found where there is some structural irregularity suggests that structure is a dominating factor.

THE CLINTON SAND

For all practical purposes the Clinton can probably be regarded as a water-dry sand, though there are places in Ohio, notably parts of Jackson and Vinton counties, where it does contain water. In the producing areas, the Clinton is a series of lenses. Consequently, in a map such as Figure 11, one cannot be positive, in working from well records, how much is real structure. In any event, whatever structure there may be in the Clinton in most of Ohio, it is nothing more than irregular terracing. There is some evidence, locally, that the volume of Clinton wells is greater along terrace fronts. The theory has been held that since the Clinton contains so little water, Clinton oil pools are synclinal. The writer has never seen anything to support the latter theory. In this connection it might be noticed that two deep Clinton tests were made in the prominent syncline in eastern Ohio shown in Figures 3 and 8. Both were located directly in the syncline as expressed by surface formations, and both were dry. Another deep test in western Guernsey County, and on the Cambridge anticline, found 100 feet of Clinton sand, but was also dry.

The older view, that the Clinton pools occur where the sand feathers out and is replaced by shale, goes as far in explanation as any. Possibly when deeper drilling is warranted another series of similar lenses may be found farther east.

[1] Rich, *Economic Geology*, Vol. 16, No. 6, p. 347.

GEOLOGY OF THE SAGINAW OIL FIELD, MICHIGAN, AND DISCUSSION OF MICHIGAN'S OIL PROSPECTS[1]

CHARLES GORDON CARLSON[2]

Tulsa, Oklahoma

ABSTRACT

The first drilling for oil at Saginaw was in 1912 by the Saginaw Valley Development Company. The wells were located on the south limb of the Saginaw anticline. Oil was found, though not in commercial quantities, in the "Saginaw sand"—a dolomitic lime in the Traverse formation. The discovery well leading to the present development was drilled in the fall of 1925 by the Saginaw Prospecting Company.

Most of the production is from the Berea sand of Mississippian age, at depths ranging from 1,800 to 1,860 feet. Wells, after being shot, produce from two or three barrels to forty barrels a day, depending upon location on structure and "tightness" of sand. The oil is of 46-degree gravity and contains about 48 per cent gasoline.

On June 1, two wells were producing from the Saginaw lime at a depth of 2,300 feet. This lime is in the Traverse formation of Devonian age. Other wells drilled to this "pay," and favorably located, have been dry.

The total production of the field on June 1 was about 1,400 barrels a day from more than 190 wells.

The limit of the field is approximately defined, except at the southeast, where the trend of the pool is into the business district.

It is probable that additional production will be found in the eastern part of the state should conditions structurally favorable be found. The thickness of glacial drift and the absence of the Berea sand in western Michigan make this part of the state less favorable for oil and gas development.

SAGINAW OIL FIELD

LOCATION

The Saginaw oil field is in the east-central part of Michigan. The field is about three miles long and extends southeast from the NW. $\frac{1}{4}$ of Sec. 10, T. 12 N., R. 4 E., into the northwest part of the city of Saginaw.

STRUCTURE

The producing wells at Saginaw are located on the Saginaw anticline, a well-defined asymmetric fold trending northwest and southeast, and extending from the northeast half of Sec. 4, T. 12 N., R. 4 E., across the cen-

[1] Presented before the Association at the Tulsa meeting, March 26, 1927.

Manuscript received by the editor, June 13, 1927.

Published by permission of the Twin State Oil Company.

[2] Twin State Oil Company. The writer is indebted to Richard A. Smith, director of the Michigan Geological Survey, and to Wayland Osgood, the Survey's petroleum geologist, for kind co-operation in furnishing much of the information for this paper.

tral part of the city of Saginaw. The data, though not conclusive, indicate that this anticline is located on a broad regional arch. The southeast limits of the structure and the amount of closure cannot be determined exactly owing to the absence of wells at this locality. The dip of the basinward or southwest limb of the fold is more than twice that of the northeast limb.

HISTORY OF DEVELOPMENT

Efforts to find oil at Saginaw were first made in 1912 by the Saginaw Valley Development Company. Ten wells were drilled in 1912 and 1913, two to the Traverse and eight to the Dundee.[1] The location of these tests was based on the best evidence of favorable structure available at that time. This evidence indicated the presence of an anticline trending southeast from a point about three miles west of Kawkawlin through Saginaw and Blackmar. The data were insufficient to indicate definitely the trend or position of the fold.

None of the wells drilled found oil in commercial quantities, though several of them obtained considerable oil from the Dundee (Corniferous) lime and a lime in the Traverse formation. The latter "pay," though a lime, was named the "Saginaw sand." The wells obtaining production were located in the city of Saginaw, near the Bristol Street bridge in the SW. $\frac{1}{4}$ of Section 24 (Fig. 1).

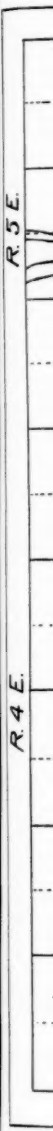
The discovery well, which led to the development of the Saginaw field, was drilled in the fall of 1925 by the Saginaw Prospecting Company, composed of Saginaw business men. This well, which produced about 20 barrels initially after being shot, is still producing several barrels a day. It is located about a mile and a half northwest of the wells which had some production in 1912 and 1913 and later development has shown it to be near the axis of the structure.

PRODUCTION AND SAND CONDITIONS

Most of the Saginaw oil is obtained from the Berea sand (Fig. 2) at depths ranging from about 1,800 to 1,860 feet, depending on the location of the anticline. The deepest producing well is the Sun Oil Company's Henry Deibel in the NW. $\frac{1}{4}$ of Section 10, the Berea here being found at 1,864 feet. This appears to be an edge well and approximately limits the northwest extension of the pool.

The Berea oil is found in the uppermost few feet of the sand. Below this "pay" there is a shale break and the sand below this shale carries water.

[1] Richard A. Smith, *Michigan Geol. Survey*, Publication 14 (11th ser.), p. 127.



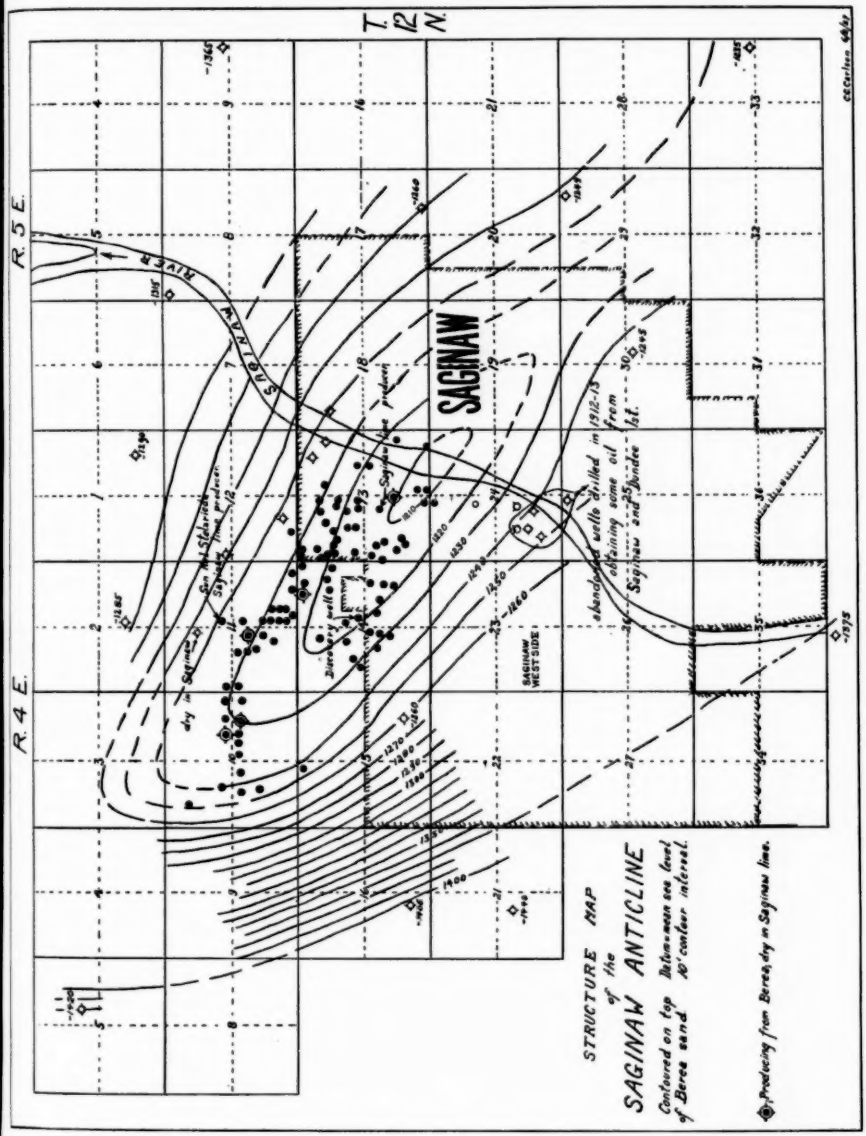

T. 12 N.
R. 5 E.
R. 4 E.
SAGINAW
SAGINAW WEST SIDE
STRUCTURE MAP
of the
SAGINAW ANTICLINE
Contoured on top Bedford-Berea contact
of Berea sand 20' contour interval.
Producing from Berea dry in Saginaw lines.

FIG. 1

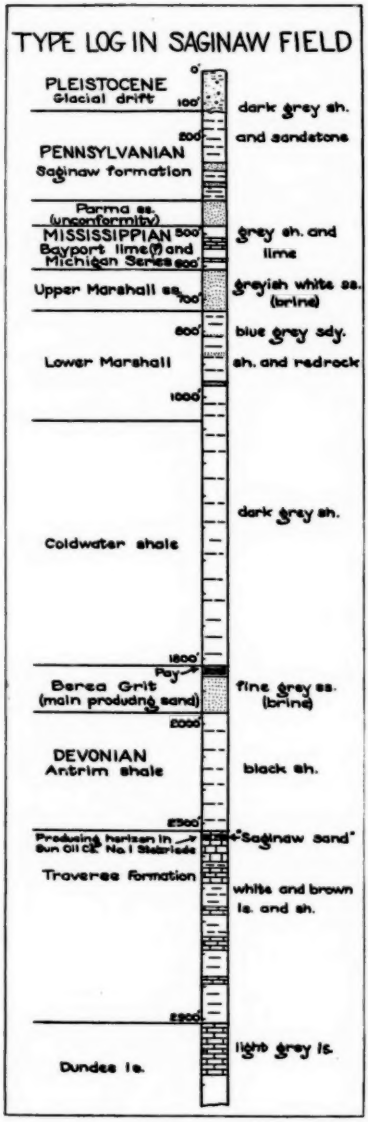


FIG. 2

Very little gas accompanies the oil. The wells are shot with 60 to 80 quarts of nitro-glycerin in order to be made commercially productive. The initial yield varies from 2 or 3 barrels to about 40 barrels a day. Wells drilled within the city limits in the southeast part of the pool have had the highest initial production. These wells are located near the top of the fold.

The decline in production is slow; some of the early wells in the field which yielded 15 to 20 barrels initially are still producing nearly this amount.

The Berea sand is fine grained, most of the grains passing through 180-mesh. Locally the sand is cemented and very silty, so that there is considerable variation in yield from different wells in the same part of the pool.

There are at present two producing wells from the Saginaw lime—so-called "Saginaw sand"—of the Traverse formation, which is Devonian in age. This production comes from about 500 feet below the Berea. Several wells have tested the Saginaw lime and on favorable parts of the structure, surrounded by Berea production, but without success (Fig. 1). The Sun Company's Stelzriede No. 1, the Saginaw lime discovery well, which was drilled late in March, 1927, had an initial production of about

475 barrels. On June 1 this well was pumping 50 barrels daily. Production within the Saginaw lime seems to be determined as much by locally porous conditions within the lime as by location on structure. The producing part of the lime in the Sun Company's well is about 4 feet thick.

Below the Saginaw lime there is possibility of production from the Dundee (Corniferous) lime, the Monroe formation, and the Trenton limestone. These formations have been very productive in the Ontario fields and along the Cincinnati Arch in northern Ohio.

Two wells have tested the Dundee lime in the Saginaw field: that of the Bliss Petroleum Company in the SW. ¼ of Section 10, and the J. and S. Development Company's well in the NE. corner of the SW. ¼ of Section 14. These wells both had encouraging showings, but owing to mechanical difficulties had not been completed as producers on June 1.

The depth to the Trenton limestone at Saginaw is probably about 5,500 feet.

On June 1, more than 190 wells in the Saginaw field were producing daily about 1,400 barrels. Less than 100 barrels of this production is from the Saginaw lime. Much of the production is from town-lot wells in the northwest part of Saginaw.

An analysis of Berea crude made by the Shaeffer Refining Company at Cushing, Oklahoma, and obtained through the courtesy of James H. Gardner is given below:

CHARACTER OF THE OIL

Gravity 46.3

	Per Cent		Per Cent
Gasoline	48	Wax oil	12
Kerosene	14	Residuum	6
Gas oil	20		100

OIL PROSPECTS ELSEWHERE IN MICHIGAN

On the areal geologic map (Fig. 3) are indicated localities at which oil has been reported from wells drilled for oil or gas. These showings in western Michigan were found in the top of the Dundee lime. The most encouraging showings were found at Allegan and Manistee. At Allegan the Dundee was found at depths ranging from 1,275 to 1,318 feet. Two of the wells for a time pumped 2 or 3 barrels daily. Very little gas accompanied the oil. At Manistee considerable oil and great gas pressure were found in a sandy limestone at 1,905 feet. As the Dundee cannot here be distinguished from the Monroe (Silurian) beds, the oil at Manistee may have come from the latter formation.

Oil was produced in small quantities near Port Huron from about 1898 to 1920 by the G. B. Stock Xylite and Grease Company. The oil was found in the sandy upper part of the Dundee limestone at depths ranging from 500 to 650 feet. The initial yield varied from 2 to 5 barrels a day,

FIG. 3

which settled after a few months to a daily production of about half a barrel.

At Mount Pleasant a showing of oil of 47-degree gravity was found in a black sand at 2,590 feet, which is probably the Berea.

In Monroe County several of the wells drilled to the Trenton limestone have found some oil and gas, though not in commercial quantities. Monroe County is located well down on the northwest flank of the Cincinnati anticline.

The lower part of the Antrim shale is generally petroliferous and, according to Dr. Smith, "The Devonian formations, especially the Antrim and Dundee, can be traced across southeastern Michigan by a line of 'shale' and surface gas wells and gas springs."[1]

The southern peninsula of Michigan is structurally a broad, shallow basin, the deepest part of which is in Midland and Isabella counties. The development of the Saginaw field, on an anticlinal fold on the eastern side of this basin, suggests that other pools may be found in this part of the state, if structures favorable to oil accumulation are found.

The formations which may be productive of oil or gas are the Berea sandstone, the Traverse formation, the Dundee limestone, Monroe formation, and Trenton limestone. The Berea sandstone is only present in eastern Michigan, being absent in the western part of the state or represented there in places by red sandy shale.

As most of southern Michigan is covered by glacial deposits, structural data can be had only from well records. Owing to the lack of reliable records in many parts of the state, core drilling may prove practical where reliable markers can be had at shallow depths and where the glacial drift is not too thick.

The structure mapping which has been done on coal seams within the Saginaw formation indicates that such "structures" are depositional or due to slumping and settling of the coal beds and are not reflected in the lower strata. The top of the Marshall sandstone is the highest formation, stratigraphically, which can be depended upon for correlation purposes.

[1] *Op. cit.*, p. 128.

ORDOVICIAN CORRELATIONS IN OKLAHOMA[1]

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ABSTRACT

The following correlations are made:

The Viola ("white") lime of the oil fields, with the uppermost limestone in contact with the Chattanooga shale near Tahlequah, and with the upper part of the Viola limestone in the Arbuckle Mountains.

The "post-Wilcox" well cuttings, with the Bromide formation in the mountains, and with the Tyner sediments between the Viola lime equivalent and the "Burgen" sandstone near Tahlequah.

The "true Wilcox" sand, with the first thick ridge-forming sandstone below the base of the Viola limestone in the mountains, with the "Burgen" sandstone at Tahlequah, and, possibly, with the St. Peter sandstone of Missouri and Iowa.

The green-shale series found in wells stratigraphically below the "Wilcox" sand with the main body of the Simpson formation.

The "Hominy" sand of the oil fields with one of the lower Simpson sands, and, possibly, with the Everton sand of Missouri.

The "Siliceous lime," with the unnamed Ordovician dolomite at Spavinaw, and with a part of the Arbuckle lime in the mountains.

INTRODUCTION

The Ordovician beds exposed in the Arbuckle Mountains are, in descending order, the Viola limestone, the Simpson formation, and the Arbuckle limestone. Near Tahlequah, in northeastern Oklahoma, a limestone now known to be the Viola limestone occurs at the top of the Tyner formation, and the Tyner formation is underlain by the St. Peter sandstone. At Spavinaw, in northeastern Oklahoma, unnamed Ordovician dolomite[2] flanks the granite outcrop. Deep wells drilled in that part of the Mid-Continent field which lies in Oklahoma encounter different beds of Ordovician age, many of which have been given misleading and confusing names.

Differentiation of the Ordovician strata penetrated by the drills was attendant on careful and extensive sample examination. No attempt will here be made to describe the lithologic and petrographic characteristics of

[1] Read before the Association at the Tulsa meeting, March 25, 1927. Manuscript received by the editor, May, 1927.

[2] Cotter in age, from fossils identified by C. L. Dake, personal communication.

the different Ordovician beds. The petrographic criteria, which served as a basis for the conclusions here drawn, should be discussed in detail elsewhere.

There is ample evidence of a period of uplift and erosion between the close of Arbuckle and beginning of Simpson deposition, as discussed by Luther H. White[1] and as shown by the overlap of different members of the Simpson formation on the "Siliceous lime" in some areas, notably on such geologic structures as that in the Garber field. Another unconformity occurs at the top of the Simpson formation. White[2] mentions the fact that "the Viola varies in thickness due to the absence of the lower beds." This variation could have been brought about only by the deposition of the Viola limestone on an unevenly elevated and eroded topographic surface. Furthermore, the writer's studies have shown that the Viola limestone is not everywhere in contact with the same part of the Simpson formation, and, in places, the Simpson beds undoubtedly suffered further erosion during the Hunton-Chattanooga hiatus. The distribution of the Simpson sediments, as they occur underground in the Mid-Continent field, was influenced, therefore, by pre-Simpson topographic conditions, and has been modified materially by post-Simpson and post-Hunton periods of uplift and erosion, so that the problem of differentiating and correlating the Simpson beds becomes extremely complex.

Much work remains to be done before there can be any general uniformity and agreement concerning the Ordovician correlations in Oklahoma. In no sense is it the intention to imply that the correlations suggested in this paper are final, but merely to contribute to the subject some conclusions, drawn by the writer from several years of study, concerning the equivalency of Ordovician units in different parts of Oklahoma, with the hope that other students of the subject will aid in the ultimate solution of this important problem.

THE VIOLA LIMESTONE

The Viola limestone in the Arbuckle Mountains is several hundred feet thick, and consists of three members (Fig. 1). These are in descending order: (1) a coarsely crystalline, gray, buff, or reddish-brown fossiliferous limestone, in places as much as 50 feet in thickness, Richmond in age; (2) about 700 feet of limestone carrying graptolites in the base, Trenton or

[1] "Subsurface Distribution and Correlation of the Pre-Chattanooga ('Wilcox' Sand) Series of Northeastern Oklahoma," *Okla. Geol. Survey Bull. 40-B* (June, 1926), p. 11.

[2] *Op. cit.*, p. 18.

Cincinnatian in age; (3) a massive, dense, buff-colored "lithographic" limestone, as much as 200 feet in thickness, upper Black River in age.

Near Tahlequah, two members of the Viola limestone outcrop, the upper, coarsely crystalline member, underlain by the lower "lithographic member." The total thickness of these two beds does not greatly exceed 20 feet. Fossils from the lower member were identified by Ulrich[1] as "lower Trenton or Black River in age." Fossils from the upper member, which

STANDARD DIVISIONS	OKLAHOMA ARBUCKLE SECTION	OKLAHOMA MID-CONTINENT SECTION	OKLAHOMA TAHLEQUAH SECTION	MISSOURI (After Dake)
RICHMOND	FERNVALE LS. (Upper Viola)	FERNVALE LS. (Upper Viola)	TYNER FM. (Richmond member)	MAQUOKETA SH. FERNVALE LS.
MAYSVILLE AND EDEN	Hiatus	Hiatus	Hiatus	Hiatus
TRENTON	VIOLA LS. (Middle)			KIMMSWICK LS.
BLACK RIVER AND LOWVILLE	UPPER BLACK RIVER (Lower Viola)	LITHOGRAPHIC LS. (Lower Viola)	TYNER FM. (Lithographic member)	DECORAH(?) PLATTIN LS.
	BROMIDE FM.	BROMIDE FM. (Post-Wilcox)	TYNER FM.	JOACHIM LS.
UPPER CHAZY OR BLOUNT		TRUE WILCOX SS.	BURBEN SS.	ST. PETER SS.
LOWER CHAZY OR STONES RIVER	SIMPSON FM.	"TYNER" Green shale series	?	Hiatus
		"HOMINY" SS.	?	EVERTON SS.
BEEKMANTOWN OZARKIAN	ARBUCKLE LS.	SILICEOUS LS.	?	POWELL LS. COTTER LS. JEFFERSON CITY ROUBIDOUX

FIG. 1.—Ordovician correlation table for Oklahoma

evidently was not seen in the original survey, nor described by Taff in the Tahlequah folio, have been identified as Richmond in age.[2] The middle member of the Arbuckle Mountain outcrops is, therefore, absent near Tahlequah.

The cuttings from wells which encounter the "white lime," in the Mid-Continent field, show the presence of the same two members which outcrop near Tahlequah, namely, the coarsely crystalline, white or gray Richmond bed, and the dense buff "lithographic stone." These two members, together, have an average thickness of about 40 feet.

To summarize: the Viola limestone, as it is encountered in wells in the

[1] *Geologic Atlas of the United States, Tahlequah Folio, No. 122* (March, 1904), p. 2.

[2] George S. Buchanan, Carter Oil Company, Tulsa, personal communication.

Mid-Continent field and found in the outcrops near Tahlequah, consists of two members, an upper, coarsely crystalline, Richmond bed, and a lower dense, buff "lithographic" bed, probably upper Black River in age. In the Arbuckle Mountains a thick series of limestones, Trenton in age, occurs between the Richmond and upper Black River members, but this Trenton series is absent in the other occurrences of Viola lime found in Oklahoma. The absence of this middle member, in Oklahoma north of the mountains, confirms the hiatus, mentioned by Dake,[1] between the Richmond and lower part of the Viola limestone in the Arbuckle Mountains, but indicates that the stratigraphic break was much greater throughout the Mid-Continent field than it was in the mountains.

According to Ulrich[2] and others, the Richmond fauna is Silurian and not Ordovician in age, and Ulrich,[3] Dake,[4] and White[5] correlate the upper (Richmond) Viola with the Fernvale limestone of Arkansas and Missouri.

SIMPSON FORMATION

The highest member, stratigraphically, of the Simpson formation, both in the surface exposures and in well cuttings, is a series of magnesian limes and sands, in places interbedded with small amounts of green shale. This series ranges in thickness from 495 to 315 feet in several measured sections made in the Arbuckle Mountains,[6] and from 600 feet to total absence in Mid-Continent wells. The descriptive term "post-Wilcox" was applied by White[7] to these beds to indicate that part of the Simpson formation which is younger than the "Wilcox" sand.

Ulrich[8] classified the Bromide formation as occurring between the Simpson formation and the Viola limestone. Taff mapped the type locality of the Bromide formation, near Bromide, Oklahoma, Sec. 19, T. 1 S., R. 8 E., as lower Viola limestone. This outcrop was visited recently by a party of geologists under the direction of the Oklahoma Geological Survey, and all present agreed that this outcrop is made up of sediments that in every way resemble the "post-Wilcox" well cuttings. Petrographic analyses

[1] "The Problem of the St. Peter Sandstone," School of Mines and Metallurgy, Univ. of Mo. Bull., August, 1921. Plate 1.

[2] E. O. Ulrich, "Relative Values of Criteria Used in Drawing the Ordovician-Silurian Boundary," *Bull. Geol. Soc. Amer.*, Vol. 37 (1926), pp. 280–347.

[3] *Bull. Geol. Soc. Amer.*, Vol. 22, No. 3 (1911), Plate 7.

[4] *Op. cit.*, p. 62. [5] *Op. cit.*, p. 18.

[6] Some sections were made by Richard Higgins, formerly in the employ of the Skelly Oil Company, and presented to the writer through the courtesy of F. C. Greene.

[7] *Op. cit.*, p. 16.

[8] E. O. Ulrich, *Bull. Geol. Soc. Amer.*, Vol. 22, No. 3 (1911), Plate 7.

were made of a sand sample collected from the outcrops, and these analyses are similar to a great many that have been obtained from "post-Wilcox" well samples. The Bromide formation, as correlated by Ulrich, is said to be Blount or upper Chazy in age. Dake states[1] that the fauna collected from the first three hundred feet of sediments underlying the Viola lime shows a "dominance of Black River species, particularly of the Platteville and Decorah beds." Micropaleontological evidence concerning the age of the "post-Wilcox" well cuttings is extremely meager, but the writer believes that all evidence at present available indicates that the "post-Wilcox" well cuttings correlate with Ulrich's Bromide formation. It is suggested by White, the writer, and others that the term "post-Wilcox" be dropped and that the name Bromide be retained to designate the group of sediments that occurs between the "Wilcox" sand and the Viola lime.

The Tyner formation of the Tahlequah quadrangle, northeast of the Arbuckle Mountains, has a range of 60 to 100 feet in thickness. The two thin fossiliferous limestone beds underlying the Chattanooga shale near Tahlequah are now known to correlate with the Viola limestone.[2] The Tyner formation underlying these limestone beds is reported as non-fossiliferous,[3] and consists of interbedded thin layers of brown sandstone, chert, brown dolomitic limestone, and green sandy shale. The Tyner outcrops have been visited several times by the writer, and many samples collected, which have been studied petrographically both by means of thin sections and heavy mineral analyses. The results of these studies offer very strong evidence that the part of the Tyner formation occurring below the Viola lime equivalent correlates with the "post-Wilcox" well cuttings and with the Bromide group of sediments in the Arbuckle Mountains. In other words, the sediments occurring, near Tahlequah, between the Chattanooga shale and the "Burgen" sand probably represent the same time interval as the combined Viola ("white") lime and "post-Wilcox" beds lying below the surface in the Mid-Continent field, and the combined Viola and uppermost Simpson beds outcropping in the Arbuckle Mountains.

From 300 to 500 feet below the top of the Bromide formation in the Arbuckle Mountains occurs a sand bed ranging from 100 to 180 feet thick which in many places forms ridges. This is a very pure, clean, quartz sand, in which the grains are fine and uniform in size. Many of the grains are rounded and frosted but in many this condition is masked by secondary enlargement. Heavy mineral analyses of several samples collected from the outcrop of this thick, ridge-forming, white sand, indicate that it

[1] *Op. cit.*, p. 58. [2] White, *Op. cit.*, p. 17. [3] Dake, *Op. cit.*, p. 52.

correlates with the so-called "true Wilcox" sand of the Mid-Continent field, which in nearly every location drilled produces either a hole full of salt, or sulphur, water, or gas or oil.

The "Burgen" sand, at the outcrops near Tahlequah, is non-fossiliferous, but underlies the Tyner formation, here correlated with the Bromide formation. The "Burgen" sand, then, occupies the same stratigraphic position as the "true Wilcox" sand of the oil fields, which underlies Bromide beds, and as the equivalent of the "true Wilcox" sand in the Arbuckle Mountain outcrops, which also occurs below some 400 feet of Bromide sediments. Heavy mineral analyses of the "Burgen" sand at its type locality are comparable in every way to those of "true Wilcox" sand and to those of the equivalent of the "Wilcox" sand in the Arbuckle Mountain outcrops. Since there is no published paleontologic evidence concerning the correlation of the "Burgen" sand with other sands in Oklahoma, present conclusions must be based on such evidence as can be obtained from stratigraphic position and petrographic characteristics, which considerations indicate that the "Burgen" sand at Tahlequah correlates with the "true Wilcox" sand of the Mid-Continent field and with the equivalent of the "true Wilcox" sand in the Arbuckle Mountain outcrops.

The name "Burgen" has been dropped from Oklahoma stratigraphy, and the "Burgen" sand has been called St. Peter sand on the new geologic map of Oklahoma. The only published statement concerning the Burgen–St. Peter correlation follows: "The 'Burgen' sandstone of Oklahoma is correlated by Ulrich with the St. Peter sandstone of northern Arkansas and numerous other states in the Mississippi valley."[1] A section was recently measured across the outcrops on the south flank of the Arbuckle Mountains, north of Ardmore, and correlated in accordance with the fossils that were found by Ulrich and others who measured the section. In this section, the "Burgen" sandstone is placed 380 feet below the "Wilcox" sand, and just above the 900-odd feet of lower Chazy or Stones River Simpson, limes and shales, yet the same geologists, who measured and correlated these beds, sent a copy of the section to the writer with the following notation:

> The St. Peter sandstone lies *below* the Chazy and it appears likely that the horizon of the St. Peter sandstone does not outcrop on the flanks of the Arbuckles unless it is represented by some of the sandy limestones or limy sandstones occurring in the top of the Canadian series and just a few feet below the base of the Chazy.

[1] C. N. Gould, "Index to the Stratigraphy of Oklahoma," *Okla. Geol. Survey Bull. 35* (1926), p. 55.

A discrepancy in the paleontologic correlations is, therefore, evident, since the paleontologists have correlated the "Burgen" with the St. Peter sand, have placed the "Burgen" sand in the Arbuckle Mountain section, and yet have reported that there is, probably, no St. Peter equivalent in the Arbuckle section. In view of this paleontologic confusion, the writer believes that the petrographic criteria may be of some value in the solution of this problem. Analyses have been made of many samples of St. Peter sand from widely scattered areas in Missouri, and the character of the quartz grains, the shape and size of the heavy mineral grains, the component heavy minerals and their percentages are entirely similar in St. Peter, "true Wilcox," and "Burgen" sand. It is suggested by the writer that the so-called "Burgen" sand, placed 380 feet below the "Wilcox" sand in the measured section north of Ardmore, may correlate with the "Hominy" sand of the oil fields rather than with the "Burgen" at Tahlequah. It is evident that a great deal more work will have to be done, both by the paleontologists and petrographers, before the St. Peter–Burgen–Simpson correlation can be proved or disproved, but the evidence available at present suggests that the "Burgen" sand correlates with the "true Wilcox" sand, with one of the Ordovician sandstones outcropping in the Arbuckle Mountains, and that both may correlate with the widespread St. Peter sand in the upper Mississippi valley.

Wells drilled in northern and northeastern Oklahoma encounter, below the "Wilcox" sand, or below the Chattanooga shale, if the upper Simpson and Viola beds are absent, a series of green shales, green shaly sands, and thin dolomitic limes called by many the Tyner series. Petrographic studies indicate that there are no outcrops in the Tahlequah area which correlate with the green-shale series occurring in wells below the "Wilcox" sand, but that this green-shale series does correlate with the interbedded dolomitic limes, sands, and green shales which make up the main body of the Simpson formation in the Arbuckle Mountains.

The base of the green-shale series is generally shown in wells by a thin dolomitic lime, closely resembling the "Siliceous lime," which is in many places underlain by a thin sand layer, although the sand and lime may be mixed in well samples. This is the "Hominy" sand, although, as stated by White,[1] the original production near the town of Hominy probably came from the "Siliceous lime." Analyses of this "Hominy" sand are very similar to those of the Everton sand of Missouri.

If the St. Peter sandstone of Missouri correlates with the "Burgen" sandstone of the Tahlequah area, and with the "Wilcox" sand of the Mid-

[1] *Op. cit.*, p. 14.

Continent oil field, and if the Everton sand of Missouri correlates with the "Hominy" sand, the whole green shale series occurring in the Mid-Continent field between the "Wilcox" and "Hominy" sand is represented in Missouri by the "slight hiatus"[1] between the St. Peter sandstone and the Everton formation, or in other words, the green shale series below the "Wilcox" sand in the oil fields thins toward the northeast to the point where it is absent in Arkansas and Missouri.

In a few places, wells have encountered a sand, below the "Hominy" sand, which differs markedly in its petrographic characteristics from "Hominy" sand. This basal sand may or may not be in the nature of an erosion product, as it has been seen too rarely to yield conclusive evidence one way or the other. Dake states[2] that "the basal sandstones of the Simpson, then, are probably actually older than the Everton," and there is some evidence in support of his view.

"SILICEOUS LIME"

The writer has very little to contribute to a discussion of the Arbuckle-Siliceous limestone, except to agree with those who have suggested that there was elevation and erosion of the "Siliceous lime" before the deposition of beds of recognized Simpson age, so that the top of the "Siliceous lime," as it is encountered by wells in widely scattered areas, is probably not always the same part of the "Siliceous lime," and to point out the fact that, lithologically, the "Siliceous lime"so resembles lime members of the Simpson formation that it is extremely difficult, and in places hazardous, to make a positive "Siliceous lime" correlation.

Because of the great thinning of all the Ordovician beds toward the north, the Arbuckle lime probably never can be traced by drill holes continuously from its outcrops in the mountains to the "Siliceous lime" of the northern Mid-Continent region, but the correlation of the "Siliceous lime" of the oil fields with the unnamed Ordovician dolomite at Spavinaw, Oklahoma, seems to have been fairly well established by well logs. The dolomite at Spavinaw is said, on paleontological evidence, to correlate with the "Swan Creek zone" of the Cotter formation in Arkansas and Missouri, of Canadian age,[3] which, if the well-log correlation is reliable, indicates that the "Siliceous lime" also is Canadian in age. Since a part of the Arbuckle lime in the mountains is correlated by Ulrich as Canadian, this part of the Arbuckle lime, the "Siliceous lime," and the dolomite at Spavinaw are, probably, correlatives.

[1] Dake, *op. cit.*, Plate 1.

[2] *Ibid.*, p. 60.

[3] White, *op. cit.*, p. 11.

SUMMARY

The writer suggests the following correlations for the Ordovician beds of Oklahoma:

1. The limestone which, in places, directly underlies the Chattanooga shale at Tahlequah, the so-called "white lime" of the oil fields, the upper part of the Viola lime encountered by wells, and the upper part of the Viola lime in the Arbuckle Mountains are equivalents, are Richmond (uppermost Ordovician or lower Silurian) in age, and correlate with the Fernvale limestone of Arkansas and Missouri.

2. The Bromide group in the Arbuckle Mountains, the "post-Wilcox" beds encountered by drills, and that part of the Tyner formation at Tahlequah which occurs between the Viola lime equivalent and the "Burgen" sandstone, are correlatives.

3. The first thick, white, ridge-forming sandstone below the Viola lime, in the Bromide formation at its outcrops, correlates with the "true Wilcox" sand of the oil fields, with the "Burgen" sand near Tahlequah, and, possibly, with the St. Peter sandstone.

4. The series of green shales, shaly sands, and dolomitic limes encountered by wells, below the "Wilcox" sand in northeastern Oklahoma, would occur, if present at Tahlequah, below the "Burgen" sand. This series is represented in Arkansas and Missouri by a hiatus between the St. Peter and Everton sands, and correlates with the main body of the Simpson formation in the Arbuckle Mountains.

5. The "Hominy" sand of the oil fields is equivalent to one of the lower sand members of the Simpson formation in the mountains, and may be equivalent to the Everton sand of Missouri.

6. Simpson beds older than the Everton are present in the mountains and have been seen in a few wells in the Mid-Continent field.

7. The top of the "Siliceous lime," as encountered by wells, is an erosion surface truncating beds of somewhat different ages. The so-called "Siliceous lime," the Ordovician dolomite at Spavinaw, and the top of the Arbuckle lime in the mountains are, roughly, equivalent to one another. It should, however, be borne in mind that there are dolomitic lime beds within the Simpson sediments which, lithologically, very closely resemble the "Siliceous lime," and since microfossils in these limes are, practically, absent in well cuttings, great care should be taken before a positive "Siliceous lime" correlation is made.

THE PROOFS OF THE CARBON-RATIO THEORY[1]

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ABSTRACT

Although several geologists have questioned the validity of the carbon-ratio theory, they admit its practical value; the writer, therefore, does not cite evidence of the relation between isocarbs and oil and gas occurrence, but presents the available data indicating that this relationship is produced by tectonic forces more than by conditions of sedimentation. The evidence considered is from the laboratory and the field. The writer concludes that the experimental data regarding the generation of oil and gas from bituminous rocks are at present too meager to furnish any definite evidence regarding the validity of the carbon-ratio theory; that the field evidence indicates that the porosity of sandstones and other reservoir rocks is reduced by dynamic alteration and that this decrease in pore space is an important factor in causing the absence of oil in areas containing coals of high carbon ratios; that the intense deformation of rocks causes the oil and gas to escape, and that this is one reason why they are absent from areas that have been acted on by great tectonic forces; that the tendency for gas rather than oil to occur in areas of greater alteration is probably due chiefly to the lower porosity of these rocks and to the action of dynamic pressures on the source material, though the variations in the conditions of sedimentation may have been operative also; and that the distribution of marine bituminous strata in the three geosynclines that may be used to test the carbon-ratio theory shows that dynamic alteration and not the conditions of sedimentation is chiefly responsible for the barrenness of the areas in which the carbon ratios of the coals are high.

INTRODUCTION

During recent years several geologists have published papers in which they question the validity of the carbon-ratio theory of David White.[3] It is true that these writers do not question the practical value of the hypothesis, but claim that the absence of oil in the areas where the coals have a high content of fixed carbon is due to the change in the conditions of sedimentation rather than to the influence of tectonic forces. Nevertheless, the problem is of important practical significance, for there are certain regions in which the conditions of sedimentation are favorable for the development of oil pools, but where, according to the carbon-ratio theory, there should be no production. There is a double reason, therefore, for making a careful evaluation of the proofs of this important theory.

[1] Manuscript received by the editor, June 27, 1927.

[2] Geological department, Venezuelan Gulf Oil Company.

[3] David White, "Some Relations in Origin between Coal and Petroleum," *Jour. Wash. Acad. of Sciences*, Vol. 5, No. 6 (1915), pp. 189–212.

COMPOSITE NATURE OF THE CARBON-RATIO THEORY

Before proceeding to an examination of the proofs, it is of course advisable to state definitely the nature of the theory which it is proposed to test. In its original statement four distinct propositions are found: (1) the absence of oil and gas in regions of high carbon ratios (more than 85); (2) the occurrence of oil and gas fields in areas of medium carbon ratios (50 to 65); (3) the occurrence of gas in areas of higher carbon ratios than those in which oil is found; (4) the occurrence of lighter oils in areas of higher carbon ratios. A fifth and very important division of the theory, added by Fuller[1] in 1919, is that the porosity decreases toward areas of higher carbon ratios. A sixth proposition, that oil production is absent or relatively rare in strata closely associated with coals of very low carbon ratios, such as lignites, brown coals, and peat, may also be included in the theory.

It should be mentioned that these different subdivisions are not mutually dependent on one another. If it could be shown that one was completely valueless this would not mean that the others were discredited. If, for example, the fourth, which is supported by the least evidence, were disproved, this would in no way affect the value of the first.

The idea that petroleum after it has entered the oil sands has been changed to gas, with or without carbonization, a conception that has been attacked with such energy by the opponents of the theory, is not a part of it at all.

The alternate hypothesis, proposed by McCoy,[2] Tarr,[3] and Dorsey,[4] admits that it is possible to estimate the oil possibilities of untested regions by means of the carbon ratios of the coals, but claims that this is brought about by a change in the conditions of sedimentation toward the areas of high fixed-carbon content, particularly by the change from deposition in the sea to deposition on land.

The purpose of the writer is not to cite evidence that there is a relation between the isocarbs and oil and gas production, but to consider whether the available data indicate that this relationship is produced by the conditions of sedimentation or by tectonic forces.

[1] M. L. Fuller, "Relation of Oil to Carbon Ratios of Pennsylvanian Coals in North Texas," *Econ. Geol.*, Vol. 14 (1919), pp. 536–42; "Carbon Ratios of Carboniferous Coals of Oklahoma, and Their Relation to Petroleum, *ibid.*, Vol. 15 (1920), pp. 225–35.

[2] A. W. McCoy, "A Short Sketch of the Paleogeography and Historical Geology of the Mid-Continent Oil District and Its Importance to Petroleum Geology," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 5 (1921), pp. 541–84.

[3] R. S. Tarr, "Oil May Exist in Southeast Oklahoma," *Oil and Gas Jour.*, Vol. 24, No. 30 (1925), p. 51.

[4] G. E. Dorsey, "The Present Status of the Carbon Ratio Theory," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 455–65.

EXPERIMENTAL EVIDENCE

Evidence in proof or disproof of the carbon-ratio theory may be obtained from two sources, the field and the laboratory. Owing to the composite nature of the theory, it is necessary to consider the evidence regarding each portion separately. The absence of oil and gas in regions of great regional alteration is due, according to the carbon-ratio theory, to the reduction in porosity, which would prevent these fluids from flowing into the wells even if they were present, and in part to their escape through the faults and fractures opened during the intense deformation. No doubt the closing of the rock pores by high pressures and the escape of the oil and gas could both be imitated in the laboratory, but the conditions in the laboratory are so different from those in the field that it is not likely that any adequate evidence would be obtained from such experiments.

It might be supposed that the theory that lighter oil and a larger proportion of gas are generated in the areas where the pressure and heat were greater is better suited for being tested in the laboratory. In fact, Dorsey[1] has cited the results of distilling crude oil in the refinery as experimental data disproving the carbon-ratio theory. A careful consideration will show, however, that the analogy with refinery distillation is quite fallaceous. In the first place, as Washburne[2] showed some time ago, there has been no natural distillation of oil during its generation, for the heavier constituents of oil could not have existed as gases under the temperatures and pressures which must have existed in the source rocks during the generation of oil. Since the distillation of oil from oil shales also involves the vaporization of the constituents of petroleum, it does not furnish a reliable analogy either. Moreover, the oil shales used in the experiments along these lines are much richer in organic material than the comparatively lean bituminous shales which are generally supposed to be the source rocks of oil. At any rate, the general results of the experiments relating to the distillation of oils and oil shales seem to be in support of the carbon-ratio theory, if they have any bearing on it at all, for they indicate that variations in the temperature, pressure, and other conditions have an important effect on the quality of the resulting oils, and on the proportions of oil to gas. Hence these experiments suggest that the variations in these conditions which are known to occur with the increase in the carbon ratios of the coals may account for the change in the gravity of the oils and in the proportions of gas to oil toward areas of higher carbon ratios.

There are also several general laws of chemistry and physics which may

[1] *Op. cit.*, p. 558.

[2] C. W. Washburne, "Some Physical Principles of the Origin of Petroleum," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 3 (1919), pp. 345–62.

throw some light on the manner in which variations in heat and pressure during the origin of oil and gas affect the quality and proportions of the resultant products. It is well known that an increase of pressure tends to favor the generation of substances which will relieve the pressure. If the pressure is hydrostatic it will therefore tend to favor the generation of the denser compounds, while if it is non-uniform it will tend to favor the generation of either dense compounds or compounds which are fluid and can escape from the system and so relieve the pressure. It is also well known that the heavier molecules of the substances which form oil and gas are more unstable and more readily dissociated than the lighter ones. Hence, under the comparatively low pressures and temperatures which were generated in the regions of low carbon ratios, only the heavier molecules of the parent substances might be dissociated, forming comparatively heavy oils. Under the greater temperatures and pressures which characterized the areas of high-carbon ratios, the lighter molecules might dissociate, forming lighter oils. In the regions of the most intense alteration, all of the molecules except the very lightest might have dissociated, forming only gas. Since the dissociation took place only in the source rocks during the generation of oil, any carbonaceous residue formed would be deposited there and not in the sandstones or other reservoir rocks. It is of course a well-known fact that such residues are found in the bituminous shales in the areas of great regional alteration. All this is of course merely a speculation. It is introduced to show that processes are known which might account for the generation of lighter oils and more gas in regions of higher carbon ratios.

As the writer[1] has explained at greater length elsewhere, it is possible that the effect of directive pressure has been important in the generation of oil and gas. We know that the temperatures during the generation of oil and gas were not high, and the hydrostatic or uniform pressures were also probably not much higher than those in the comparatively undeformed regions, for it is generally found by drilling that the hydrostatic pressures of the fluids in the rock pores are not much greater than is necessary to send a column of water to the surface. On the other hand, the non-uniform pressure due to the horizontal thrusts is doubtless much greater in the regions of intense deformation than in the areas of low carbon ratios. Hence a great difference in pressure would be set up between the solid particles of the shale or other source rock and the liquids in the pores, which would be under hydrostatic pressure. This might cause the

[1] W. L. Russell, "Oil and Gas Accumulation in the Clinton Sand of Ohio," *Econ. Geol.*, Vol. 21, No. 6 (1926), p. 553.

solid hydrocarbons in the shale to dissociate, forming fluid oil and gas which could escape and relieve the pressure. It need hardly be stated that no experiments have been performed which give an adequate test of this method of generating oil and gas, and certainly none has been performed which indicates how the variations in heat and pressure would affect the nature of the resultant products if they were formed in this manner. Not until an extensive series of such experiments have been completed can we expect definite experimental evidence in confirmation or disproof of this part of the carbon-ratio theory.

FIELD EVIDENCE

EVIDENCE OF METAMORPHISM

It should be remembered that what is sought here is not field evidence of the relation between the isocarbs and oil and gas production, but proof that this relationship is due to the regional alteration of the sediments by dynamic forces, and not to the original changes in the conditions of sedimentation. The general nature of metamorphism itself furnishes some evidence in support of this theory. Metamorphism is obviously due to tectonic forces, and not to any conditions of sedimentation. Though rocks are classified as metamorphic or sedimentary as though there was a hard-and-fast boundary between the two types, it is evident that there is no sudden transition from one to the other, but, on the contrary, a gradual change. This is proved by the slow, steady alteration of the various metamorphic characteristics, such as the porosity, crushing strength, density, and the carbon ratios of coals. The oil pools not only do not occur in the true metamorphic rocks, but they do not occur in a wide zone around them, where the strata, though they would be classed as sedimentary and not metamorphic, possess some of the characteristics of metamorphism. The general presence of this barren zone of intermediate character suggests that the degree of metamorphism necessary to destroy the oil and gas pools is less than that necessary to produce true metamorphic rocks. The opponents of the carbon-ratio theory would doubtless say that this was due to the conditions of sedimentation, and this objection cannot be answered definitely without considering other lines of evidence. There is, however, something suggestive in the fact that the rocks of a character intermediate between sedimentary and metamorphic are everywhere barren of oil and gas.

EVIDENCE OF POROSITY

During recent years it has been recognized that the decrease of porosity toward regions of greater regional alteration is largely responsible for

the absence of oil and gas production in these areas. This relationship has been recognized in all the three regions where the carbon-ratio theory has been tested. In areas of low carbon ratios the sandstones generally yield large flows of water when penetrated in drilling. Where the fixed carbon content of the coals is 60 to 70 per cent the sandstones are for the most part of too low porosity to yield flows of water, though there are local porous lenses or pockets from which water, oil, or gas are obtained. It is noticeable also that, when oil or gas production is found in such areas of high regional alteration, the rate of yield is in general much less than in the case of the slightly altered rocks. As explained later, this decrease in porosity tends to increase the apparent proportion of oil to gas. In the areas where the fixed carbon content of the coals is greater than 85 per cent the sandstones are apparently completely devoid of water at depth. Of course these sandstones may contain considerable volumes of water, but owing to the low porosity and the closing of the rock pores by cement, the water cannot run into the wells, and the rocks seem to be entirely dry.

It might be supposed that the absence of water is due to the change from marine to terrestrial conditions of deposition toward the areas of greater alteration, and that the sandstones are dry because the water has been removed by evaporation. In a few cases this is doubtless the true explanation, but generally it may be shown that the low porosity is the chief factor. Many of the sandstones which are now found dry were originally laid down in streams or seas, and there is in many cases no reason to suppose that they were ever dried out. Moreover, actual tests show that the porosity of these sandstones is so low that they would appear dry even if their pores were full of water.

In a recent paper the writer[1] has shown that the average porosity of the sandstones is closely related to the carbon ratios of the coals, and that, in fact, it could be used as an index of alteration in areas where the coals are absent. A series of tests showed that the porosity of the pure quartz sandstones steadily decreases toward areas of high carbon ratios, until in regions of anthracite coals it is only 1 or 2 per cent or even less. It is possible that the porosities of the sandstones laid down on land were originally somewhat lower than those formed in the sea, and this may influence the results slightly. The marine sandstones may, for example, have been better sorted and may have contained smaller proportions of the minerals other than quartz. The porosity of the poorly sorted sands is generally less than that of those which are well sorted, because the smaller grains

[1] W. L. Russell, "Porosity and Crushing Strength as Indices of Regional Alteration," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 10 (1926), pp. 939–52.

fill the space between the larger. The minerals other than quartz also tend to lower the porosity by decomposing and filling the spaces between the grains with their alteration products. However, that this is not the chief factor in the reduction of the porosity is indicated by the fact that even the well-sorted marine sandstones which are composed of pure quartz are of very low porosity in the areas of high carbon ratios. There is no more reason for supposing that the dense, quartzitic sandstones associated with coals of very high carbon ratios are produced by changes in the conditions of sedimentation than there is for attributing the development of quartzites and other metamorphic rocks to this cause. The evidence indicates that there is a gradual change from the porous rocks found in areas containing coals of low carbon ratios to the dense strata associated with coals of high carbon ratios, and finally to the genuine quartzites associated with anthracites and graphites, and there can be no doubt but that the same agencies which have produced the end products have developed the intermediate rocks when acting with less intensity.

The researches of Melcher[1] have shown that the rate of production of oil and gas is dependent on the porosity, and that if it is below a certain limit oil and gas cannot be produced in commercial quantities. Since the porosity of the sandstones associated with the coals of high carbon ratios is well below this limit, oil and gas in commercial quantities could not be produced from them even if the conditions of sedimentation were favorable. It is evident, therefore, that the relation of the porosity to the fixed carbon content of the coals affords definite proof that the absence of oil and gas production in regions of high carbon ratios is due to the regional alteration caused by tectonic forces, and not to the conditions of sedimentation.

EVIDENCE OF THE EXPULSION OF THE OIL AND GAS

There is plentiful evidence to show that oil and gas have been expelled from the sediments in regions of great alteration. In the areas of low carbon ratios the strata contain large quantities of water, and where the conditions are favorable, oil and gas. As Hedberg[2] and the writer[3] have shown, the shales and sandstones lose their porosity as they are subjected to incipient metamorphism. As the porous rocks are compacted they must

[1] A. F. Melcher, "The Texture of Oil Sands in Relation to the Production of Oil," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8 (1924), p. 716.

[2] H. D. Hedburg, "The Effect of Gravitational Compacting on the Structure of Sedimentary Rocks," *ibid.*, Vol. 10, No. 11 (1926), pp. 1035–72.

[3] W. L. Russell, "Porosity and Crushing Strength as Indices of Regional Alteration," *ibid.*, pp. 939–52.

lose a volume of water and other fluids approximately equal to the reduction in pore space. Since the characteristics of the dense strata associated with anthracites and graphites show that they were once highly porous and saturated with water, it is evident that great volumes must have been expelled. As these rocks now contain no oil or gas and no porous portions capable of holding oil or gas, it is evident that these fluids, if they were ever present, must have been expelled.

The bituminous nature of some of these highly altered strata indicates that considerable quantities of oil or gas must have been generated in them and then expelled. Such bituminous or carbonaceous rocks occur extensively in the areas of high carbon ratios in the Appalachian geosyncline, in western Kentucky and southern Illinois, and in northern Arkansas and southeastern Oklahoma. At present these formations may be metamorphosed to slates, schists, or marbles, but there is no doubt but that they were orignially bituminous or carbonaceous shales or limestones such as are supposed to be the source rocks of oil and gas. The bituminous or carbonaceous matter of these rocks is now nearly pure carbon, but since this element does not accumulate in a pure state in the strata, they must have originally contained much volatile matter. These volatile substances must have formed oil or gas as they were subjected to the heat and pressure of deformation and alteration, and the fact that these fluids are not now present is a proof that they have escaped to the surface. More definite proof that oil and gas escape during alteration or deformation is found in the well-known tendency for oil and gas seeps to occur along faults and fractures or in zones of highly disrupted strata.

EVIDENCE AS TO THE OCCURRENCE OF GAS IN AREAS OF GREATER REGIONAL ALTERATION THAN THOSE IN WHICH OIL IS FOUND

In the Appalachian geosyncline and in the geosyncline in northern Arkansas and southeastern Oklahoma there is a marked tendency for the gas pools to occur in areas of greater alteration than the oil pools. Since this relationship is so marked and is found over such great areas, it is clear that it is not due to chance. Probably it is brought about partly by the lower porosity of the sandstones in the gas fields. Since gas is much less viscous than oil, it will flow through sandstones of low porosity much more readily. Hence a productive gas field might exist in a sandstone which was too dense to produce oil. Moreover, it costs less to operate gas fields than oil fields, and for this reason, as the rate of production is reduced by the decrease in porosity, the limit of commerical production is reached first in the case of oil. Shows of oil are in many cases encountered

in the gas fields which occur in areas of considerable regional alteration. This indicates that oil is present, and it is probable that it would be produced in commercial quantities if the sandstones were sufficiently porous.

Though the effect of porosity is doubtless of some influence in causing the gas pools to occur in regions of greater alteration than the oil pools, it is apparently by no means the only factor. The almost complete absence of oil from some areas suggests that the original proportion of gas to oil was greater in such highly altered localities. It is of course possible that the original nature of the deposits has been effective in producing this result. As Tarr[1] and Dorsey[2] have suggested, there is in many places a change from marine to continental conditions of deposition toward areas of greater alteration. Hence marine bituminous rocks, yielding oil during alteration, would be likely to give place, toward areas of greater deformation, to carbonaceous strata of terrestrial origin which would yield gas. However, the fact that marine strata of various types are present in many of these gas fields indicates that this is not the sole explanation. The shore line was at different places during the deposition of the different formations. If the change from oil to gas toward areas of greater alteration is due to the change from the marine to the continental type of deposition, one would expect that the belt of oil pools in each formation would be flanked by a belt of gas pools on the landward side. As the position of the shore line varied greatly during the deposition of the various geologic formations, these belts of gas pools would not be superimposed on each other, but would be widely scattered. The fact that the gas belt occurs in the same area in several formations of different modes of origin, and the fact that this gas belt is parallel to the isocarbs, and for the most part between isocarbs 60 and 75 apparently indicate that it is produced by regional alteration and not by the changes in the conditions of sedimentation. In general, the shore line was farther toward the regions of great alteration during the middle and lower Paleozoic than during the Pennsylvanian and Permian. Hence, if the latter explanation were the correct one, one would expect the gas belt to lie farther in this direction in the older formations, whereas this is not the case.

It is evident that there are important factors other than the degree of regional alteration which influence the relative proportions of oil and gas. Extensive gas pools occur in association with coals of comparatively low carbon ratios, and methane is found in Recent and Pleistocene deposits which have not been altered at all. Nevertheless, the ratio of gas to oil is so much greater between isocarbs 65 and 80 than it is between isocarbs 50

[1] *Op. cit.* [2] *Op. cit.*

and 60 that it seems obvious that the degree of regional alteration has some influence on the relative proportions of the two fluids.

EVIDENCE AS TO THE OCCURRENCE OF LIGHTER OILS IN AREAS OF GREATER REGIONAL ALTERATION

The evidence supporting this proportion is not so conclusive as in the case of the other divisions of the carbon-ratio theory. However, it should be remembered that the value of the theory would not be seriously impaired if it were shown that there was no relation between the quality of the oil and the carbon ratios of the coals.

Certainly the effect of regional alteration is only one of the many factors which determine the gravity of oil. No doubt the original nature of the source rocks, the effect of filtration through fine sediments, reactions with the chemicals in solution in the ground water, and the evaporation of the lighter constituents, all influence the quality of petroleum. Doubtless the irregular variations in the gravity in the same sand in the same locality are due to these causes and not to the amount of regional alteration. It appears to the writer that the accuracy of this phase of the carbon-ratio theory has been greatly exaggerated. It is not possible to predict definitely what the gravity of an undiscovered oil pool will be by means of the carbon ratios of the associated coals. If the gravities of all the occurrences of oil were plotted on isocarb maps, it would appear that it is impossible to obtain any reliable idea of the degree of regional alteration from the gravity of a few small isolated occurrences of oil, as some writers have attempted to do. If these occurrences are seeps, the uncertainties are much greater, for their gravities are likely to be influenced by the effect of migration through fine sediments or by the evaporation of the lighter constituents.

According to the carbon-ratio theory, the specific gravity of oils should ot course decrease downward and toward regions of greater alteration. It is futile to attempt to disprove this supposition by citing exceptions, for a case conforming to the rule could be given for each exception cited. The best mode of making a reliable test of the theory is to compare the average gravity of all the oil produced from areas of high regional alteration with that produced from areas of low alteration, and to determine the general tendency of the variations in gravity with depth by considering all the cases in which there is production from the different horizons in the same pool. It is the belief of the writer that if this were done a general decrease in specific gravity would be found to take place downward and toward areas of greater regional alteration. The knowledge of the nature of the source rocks of oil is not yet sufficiently definite to prove that this

change is due to regional alteration and not to the original differences in the quality of the source materials, though the nature of the variations seems to favor the former explanation.

EVIDENCE AS TO THE RELATIVE IMPORTANCE OF DYNAMIC ALTERATION AND THE CONDITIONS OF SEDIMENTATION IN CAUSING THE ABSENCE OF OIL IN REGIONS OF GREAT ALTERATION

It has been shown that there is definite evidence indicating that the absence of oil and gas production in regions of great alteration is due partly to the decrease in porosity, and partly to the escape of the oil and gas in the highly deformed areas. Field evidence has been cited which proves that this decrease in porosity is due to tectonic forces and not to changes in the conditions of sedimentation. However, since the part of the carbon-ratio theory which states that oil and gas production is absent in areas of great alteration is its most valuable subdivision, and since the main thesis of those who question its validity is that this absence of production is due to the conditions of sedimentation, it seems advisable to consider which theory is supported by the field evidence as to these conditions.

It should be possible to settle this point by studying the distribution of the marine bituminous shales and limestones which are supposed to be the source rocks of oil and gas. If the absence of oil in the areas of high carbon ratios is due to the change from marine to continental conditions of sedimentation, then such marine bituminous rocks should be absent from these areas. If, on the other hand, formations of this nature are present in these areas, then it is likely that their barrenness is due to the degree of dynamic alteration. Marine bituminous strata may be found in association with sandstones or limestones in the highly altered regions in the Appalachian geosyncline, the coal fields of western Kentucky and southern Illinois and northern Arkansas and southeastern Oklahoma. Since these are the ideal stratigraphic conditions for producing oil and gas, the absence of production must be ascribed to tectonic causes. The vertical distribution of the source rocks also indicates that the absence of production is not due to the continental nature of the deposits. The shore line was generally much farther toward the land—that is, toward the areas of greater alteration—in the middle and early Paleozoic than in the Carboniferous. Hence, if the absence of production is produced by continental conditions, the belt of oil and gas pools should extend farther in this direction in these lower strata than in the later formations. As a matter of fact, the reverse is the case.

Another vindication of the carbon-ratio theory is found in the fact that where the isocarbs are not everywhere parallel to the ancient shore

lines, the belt in which production occurs seems to follow the isocarbs rather than the shore lines. For example, in western Kentucky and southern Illinois, a belt of highly deformed strata known as the Rough Creek–Gold Hill uplift cuts across the basin east and west. The carbon ratios are in general rather high in the highly disturbed strata, as Knowlton[1] and the writer[2] have shown. In the parts of this uplift where the carbon ratios are high, several steep structures have been tested with negative results, though all the conditions for production are apparently favorable except the degree of alteration and deformation.

In view of the preceding considerations, it would appear that it is the regional alteration and not the conditions of sedimentation which has caused the absence of oil from areas containing coals of high carbon ratios. Nevertheless, it is not to be supposed that the effect of the conditions of sedimentation should be neglected entirely. In a region in which extensive sedimentation is going on the seacoast is likely to be bordered by a belt of swamps in which considerable deposits of carbonaceous material may form. Farther toward the land, where the gradient of the streams would be steeper, swamps would be comparatively rare, and the strata would contain comparatively little carbonaceous matter. Meanwhile, bituminous materials might accumulate in the sea offshore. If this series were buried and folded, the marine bituminous sediments would be likely to generate oil and the carbonaceous swamp deposits would generate gas, while farther inland neither oil nor gas would be formed in any quantity. It appears, therefore, that the effect of the conditions of sedimentation must be taken into consideration, though it is subordinate to the dynamic alteration in bringing about the absence of oil in regions containing coals of high carbon ratios.

CONCLUSIONS

1. The experimental data regarding the generation of oil and gas from bituminous rocks are at present too meager to furnish any definite evidence regarding the validity of the carbon-ratio theory.

2. The field evidence definitely indicates that the porosity of sandstones and other reservoir rocks is reduced by dynamic alteration and that this decrease in pore space is an important factor in causing the absence of oil in areas containing coals of high carbon ratios.

3. The field evidence also indicates that the intense deformation of

[1] G. F. Knowlton, "Carbon Ratios and Petroleum in Illinois," *Geol. Surv. of Illinois, Report of Investigations No. 4*, 1925.

[2] W. L. Russell, "The Relation between the Isocarbs and Oil and Gas Production in Kentucky," *Econ. Geol.*, Vol. 20, No. 3 (1925).

hard rocks causes the oil and gas to escape, and that this is one reason why they are absent from areas that have been acted on by great tectonic forces.

4. The field evidence indicates that there is a tendency for gas rather than oil to occur in areas of greater alteration. This is probably due chiefly to the lower porosity of these rocks and to the action of dynamic pressures on the source material, though variations in the conditions of sedimentation may have been operative also.

5. The distribution of marine bituminous strata in the three geosynclines that may be used to test the carbon-ratio theory shows that dynamic alteration, rather than the conditions of sedimentation, is chiefly responsible for the barrenness of the areas in which the carbon ratios of the coals are high.

GEOLOGICAL NOTES

NEW PRODUCING HORIZON IN WABASH COUNTY, ILLINOIS

The Wabash County, Illinois, oil production has been obtained from several pools of small area south of the large Lawrence County fields. The principal production has been from the Biehl sand, of Chester age, found at a depth of 1,400 feet. A few wells have found a small production in another Chester sand at a depth of about 1,500 feet. Early in July, 1927, the Eastern Gulf Company drilled a deep test in the central part of the general producing area, and has evidently found commercial production in a sand at approximately 2,200 feet. This sand is thought to be in the Ste. Genevieve lime and to correspond with the McClosky sand of Lawrence County.

A second well is being deepened to test this horizon a short distance north of the Eastern Gulf well, and will be watched with much interest, for the McClosky sand in the Murphy pool, about 7 miles northeast, gave some large wells, some of which had a daily production of more than 3,000 barrels.

GAIL F. MOULTON

STATE GEOLOGICAL SURVEY, URBANA, ILLINOIS
July 8, 1927

IMPORTANT NEW DEVELOPMENTS IN SOUTHWESTERN INDIANA

At the present time two areas in southwestern Indiana are of special interest because fields larger than the average seem to have been discovered.

The first of these is a short distance east of Wabash River along the Vigo-Sullivan county line. Production here was discovered last November in the top of the Devonian limestone at a depth of 2,185 feet. Since that time two other wells have been drilled which have extended the producing area at least half a mile. This horizon has not been extensively tested farther south. It has distinct possibilities of giving production there. With the exception of the Prox well in the city of Terre Haute, Indiana,

production from the Devonian lime has been unsatisfactory in Indiana because of the non-permeable character of the reservoir rock. The only important production from this horizon in the region is in the Martinsville pool in Clark County, Illinois, about 25 miles west. The oil discovered in the Indiana field is of 47° gravity and yields 56 per cent gasoline on straight distillation.

A second pool of importance has been developed near the town of Francisco, and about 6 miles east of Princeton, in Gibson County, Indiana. Mann and Huber of Evansville, Indiana, following the recommendations of Gail F. Moulton in a private report, drilled a new test north of some older small wells, and found 150 barrels initial production. Since that time, three other wells have been completed, the best of which produced 150 barrels per day, on an average, for the first two months after being put on the pump.

The production in the Francisco pool is obtained from a Chester sand, which, according to the correlations of the Indiana Geological Survey, is the Sample sand. This sand is reached at a depth of 1,400 feet, and produces a heavy oil of about 28° A.P.I. gravity.

The oil sand is very open and continuous in this field, a condition not generally found in this part of the country. The fold on which the production is obtained is likewise somewhat more pronounced than any others which have yet been described for the general region. The principal operating difficulties are to keep from ruining the wells by drilling too deep into water, and to separate the oil when water is produced with it.

Four new wells are now producing, and four more drilling. The present production of this pool is more than 300 barrels, or more than one-eighth of the total for the state of Indiana.

The Vigo-Sullivan County pool together with the Francisco pool are principally responsible for the increase in production in Indiana this year.

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MARINE EOCENE DEPOSITS ON THE EAST SLOPE OF THE VENEZUELAN ANDES[1]

Dr. N. H. Darton, of the United States Geological Survey, recently collected on the east slope of the Venezuelan Andes specimens of a dark-colored partly crystalline limestone that carries Foraminifera of Eocene

[1] Published with the permission of the director, U. S. Geological Survey, and of the director, exploration department, Sinclair Consolidated Oil Corporation.

age. This material was collected half a mile southeast of the village of Masparito, or about 12 miles east of Calderas, in the state of Zamora (U. S. Geol. Survey locality 1/1189). On Jahn's geologic map of Venezuela[1] this locality would fall almost due north of Barinas near the eastern edge of the area mapped as schist and gneiss. This Eocene limestone is a thin bed lying near the base of a thick series of shales overlying a quartzite. Additional float material was collected on Rio Arana, west of Calderas. The collection of float limestone also contains specimens of a dark-colored Carboniferous *Productus*-bearing limestone that in gross features is surprisingly similar to the Eocene limestone. So far as known, this record, which is made available through the kindness of Dr. A. C. Veatch, is the first one of Eocene deposits in the drainage basin of the Orinoco. The float material also establishes the presence of Carboniferous limestone in the Venezuelan Andes. Heretofore, Carboniferous beds have not been reported north of Peru and the Amazon Valley in eastern Brazil.

The Foraminifera include a "*Nummulites*," a stellate "*Orthophragmina*," and a *Lepidocyclina*. The megalospheric form of the *Lepidocyclina* belongs to the subgenus *Pliolepidina* and represents *L. panamensis* Cushman[2] or a very similar species. Vaughan[3] suggests that *L. panamensis* is a synonym of *Pliolepidina tobleri* Douvillé,[4] which is based on material from Trinidad. Douvillé has never published figures showing the shape and exterior of *tobleri* and, therefore, it is not entirely recognizable. *L. tobleri* is the monotype of *Pliolepidina* Douvillé. When this name was first proposed in 1915 "*Pliolepidina* sp." was the only species assigned to it. In Douvillé's 1917 paper there is no indication that *Pliolepidina tobleri* is the "*Pliolepidina* sp." of 1915. Strictly speaking, the status of *Pliolepidina* was not fixed until the 1924 synonymy was published.

The Venezuelan *Lepidocyclina*, like *panamensis* and *tobleri*, has an unusually large nucleoconch, or embryonic shell, which in vertical sections appears rectangular and is composed of one or several chambers, depending on the plane of the section, one of which generally is extraordinarily large. A microspheric form, assumed to represent the same species, is more abundant and larger. Its test is very thick, and many lateral cham-

[1] Alfredo Jahn, *Esbozo de las formaciones geológicas de Venezuela* (1921), 108 pp., map (1:2,000,000), Caracas.

[2] J. A. Cushman, *U. S. Nat. Mus. Bull. 103* (1918), pp. 94–95, pl. 39, Figs. 4, 6.

[3] T. W. Vaughan, *Bull. Geol. Soc. Amer.*, Vol. 35 (1924), pp. 796, 797.

[4] H. Douvillé, *Compt. Rend. Acad. Sci.*, Vol. 161 (1915), pp. 727–28, Fig. 34; *Compt. Rend. Acad. Sci.*, Vol. 164 (1917), pp. 843–44, Figs. 5–6; *Mem. Soc. Géol. France*, N. S., Vol. 1, Mem. No. 2 (1924), pp. 43–44, Figs. 34–35.

bers are piled one on top of the other in vertical series. In both forms rather slender pillars, which may not reach the surface, lie between the lateral chambers.

Precisely the same couple of megalospheric and microspheric forms, both of which are very striking, are found together in the Caribbean coastal region of Colombia in beds that are considered of middle Eocene age. H. Hodson[1] records similar macrospheric forms from an unnamed locality in the Maracaibo basin. Tobler[2] has described a remarkably similar couple (*Lepidocyclina* [*Pliolepidina?*] *luxurians* Tobler) from southern Sumatra. This species is very similar to specimens from Venezuela and Colombia, but the pillars are less developed. Douvillé, and H. Hodson following Douvillé's suggestion, thought that these specimens with relatively enormous nucleoconchs might be monstrosities, but, as they have now been found on the Pacific coast of Panama, at many places in Colombia, in the Maracaibo basin, on the east slope of the Venezuelan Andes, in Trinidad, and in Sumatra, it is safe to assume that the development of these unusual nucleoconchs is a normal character. Many of the Colombian specimens on which the peripheral flange is broken off have a nucleoconch that is almost as wide as the entire umbonal part of the test.

The type material of *L. panamensis* is represented by Figure 6 of Plate 39 in *Bulletin 103* of the United States National Museum. It was collected near the mouth of Rio Tonosi, Los Santos Province, on the Pacific coast of Panama (U. S. Geol. Survey station 6586*e*). This locality probably represents the middle Eocene beds that extend far up the valley of Rio Tonosi. These beds and upper Eocene deposits in Chiriqui Province, Panama, carry the only Eocene mollusks, still undescribed, that have so far been collected between Peru and Lower California. A microspheric form at the type locality of *panamensis*, incorrectly identified by Cushman as *L. duplicata* Cushman, resembles the microspheric forms associated with the *panamensis*-like megalospheric form in Colombia and Venezuela. It is doubtful whether any of Cushman's other localities for *panamensis* can be accepted. According to Vaughan,[3] the "*panamensis*" from U. S. Geol. Survey station 6523 (recorded as 6512 in text; Pl. 39, Figs. 1–3, 5, Pl. 42), which represents an upper Eocene limestone 2 miles north of David, Chiriqui Province, Panama, is the macrospheric form of *L. duplicata* Cushman, the type specimen of which is from this locality. It has not yet been possible to confirm Cushman's record of *panamensis* from U. S.

[1] H. Hodson, *Bull. Amer. Paleont.*, Vol. 12, No. 47 (1926), pp. 27–28.

[2] A. Tobler, *Eclogae Geol. Helvetiae*, Vol. 19, No. 1 (1925), pp. 269–74, Pl. 8, 1 fig.

[3] T. W. Vaughan, *Bull. Geol. Soc. Amer.* Vol., 35 (1924), p. 796 N.

Geol. Survey station 6587, another locality near the mouth of Rio Tonosi, from which Vaughan[1] recorded middle Oligocene corals. There are two sets of *Lepidocyclina*-bearing beds in this region, and the one carrying a species that externally resembles *L. gigas* Cushman and *L. forresti* Vaughan may represent the same horizon as 6587. Cushman also doubtfully recorded *panamensis* from the Culebra formation and Emperador limestone, but these records were not based on sections. In Panama *panamensis* probably is confined to middle Eocene beds instead of occurring in "lower, middle, and upper Oligocene deposits"[2] or in "Oligocene?",[3] as Vaughan was led to believe.

L. duplicata Cushman,[4] which is found in the upper Eocene limestone of Chiriqui Province on the Pacific coast of Panama, also is a *Pliolepidina;* at all events the macrospheric form identified by Vaughan as representing *duplicata* is a *Pliolepidina.* This species instead of *panamensis* may be a synonym of *tobleri.* So far as the development of pillars is concerned, the macrospheric form of *duplicata* resembles the East Indian *luxurians. L. duplicata,* the type of which is a microspheric form, is the type by original designation of *Multicyclina* Cushman.[5] Inasmuch as the development of several layers of equatorial cells toward the periphery, which was regarded as the characteristic feature of *Multicyclina,* is found in many species, this name has been disregarded. *Multicyclina,* based on a microspheric form, seems to be a synonym of *Pliolepidina,* which was based on a megalospheric form. It is apparent that under different conditions this situation could be a fruitful source for nomenclatorial dispute.

In tropical America species of *Pliolepidina,* similar to the one collected on the east slope of the Venezuelan Andes, are found in both middle and upper Eocene deposits. The Point Bontour beds on the island of Trinidad that carry *L. tobleri* are of upper Eocene age,[6] though they were first called "Stampian" by Douvillé. They also carry a stellate *"Orthophragmina," Cisseis asteriscus* Guppy, a group that so far as known occurs only in upper Eocene deposits in America, but in Europe it also is found in the middle Eocene. Stellate *"Orthophragminas"* have been found in the float material

[1] T. W. Vaughan, *U. S. Nat. Mus. Bull. 103* (1919), pp. 207, 555.

[2] T. W. Vaughan, *U. S. Nat. Mus. Bull. 103* (1919), p. 555.

[3] T. W. Vaughan, *Bull. Geol. Soc. Amer.,* Vol. 35 (1924), p. 797.

[4] J. A. Cushman, *U. S. Mus. Bull. 103* (1918), p. 96, Pl. 39, Figs. 1–3, 5, Pl. 41, Figs. 2–4, Pl. 42.

[5] J. A. Cushman, *U. S. Nat. Mus. Bull. 103* (1918), p. 96.

[6] See G. D. Harris, *Johns Hopkins University Studies in Geology,* No. 7 (1926), pp. 101–4.

that Darton collected. Therefore, this *Pliolepidina*-bearing limestone is regarded as of upper Eocene age.

In view of the recognized Eocene age of this peculiar Pliolepidine form of *Lepidocyclina* at every locality in tropical America where confirmatory evidence is available, perhaps the assignment of the Sumatra beds carrying *luxurians* to the Aquitanian stage needs confirmation.

W. P. WOODRING[1]

U. S. GEOLOGICAL SURVEY, WASHINGTON, D.C.
June 30, 1927

[1] Introduced by L. W. Stephenson.

CORRECTION

Through an editorial error made in the discussion by Charles E. Straub on the "Effect of Gravitational Compaction on the Structure of Sedimentary Rocks," which appeared in the August number of the *Bulletin*, the heading for the column in Table I on page 890 was made to read "Surface Dip per Mile." It should have been "Amount of Surface Dip."

REVIEWS AND NEW PUBLICATIONS

Fractionation and Decomposition of Petroleum during Capillary Migration. By CHARLES W. COOK. *Econ. Geol.*, Vol. 22, No. 3 (May, 1927). Pp. 230–32. 1 fig.

It is common practice for geologists to attribute the exceptionally light and volatile nature of oils that are found in small quantities in or near oil fields, but not in the principal producing horizon, to fractionation due to migration through very fine-grained sediments. The possibility of such fractionation was pointed out long ago by David T. Day, who based his belief upon observed fractionation when petroleum was passed through fuller's earth. However, this explanation has not been applied to "stray" occurrences of oil where the oil is heavier than is normal for the pool or district. Charles W. Cook, in his short paper on fractionation of petroleum, has observed that in at least one of his experiments, oil moving out of coarse sand through a capillary tube and in contact with water, apparently has been altered so that the oil that has moved through the tube is decidedly heavier and more viscous than the original petroleum. In another experiment wherein the oil originally was in very fine sand instead of coarse sand, the oil after migration through the capillary tube apparently is lighter and less viscous than the original petroleum.

The tests are of such a nature that the observations must be taken as suggestive rather than as conclusive. However, they substantiate observations of others to the effect that the fineness of the sediments containing oil and, consequently, the fineness of the openings through which the oil moves are important factors in determining what the character of the oil shall be. Just why this should be so remains to be demonstrated, but it clearly indicates a line of experimental research that should, and undoubtedly will, be followed up.

It is of interest to note that distillation tests on bottom samples from inlets along the Atlantic Coast performed by Dr. Parker D. Trask in the course of his study of organic matter in sediments now forming, show that there is a great difference in quantity and seemingly also in quality of the distillate recovered from coarse and from fine sediments.

The experimental work of Dr. Cook has also an important bearing on oil migration. Some years ago, Chester W. Washburne suggested that gas bubbles in capillary openings would arrest migration. Professor Cook's work shows that although these bubbles retard migration, they definitely do not arrest it.

K. C. HEALD

PITTSBURGH, PENNSYLVANIA
June, 1927

Oil and Gas Possibilities at Early Grove, Scott County, Virginia. By CHARLES BUTTS. *Virginia Geological Survey Bull. 27.* Charlottesville, Virginia, 1927. 18 pp., 2 figs.

Some years ago Virginia threatened to break into the ranks of oil-yielding states when a shallow well near Rose Hill in the extreme western part of the state produced a small amount of oil. The discovery was of special interest because of its bearing on the reliability of the carbon ratio of coal as a guide to the possible presence of oil. The oil was found in an area surrounded either by Cambrian sediments or by strata which, according to the carbon ratio, were too much altered to permit the persistence of petroleum. However, in the midst of this unfavorable territory there was a block of sediments of Carboniferous and older ages which had been protected from dynamic metamorphism by a thrust fault on the east that had relieved the pressure of the westward-crowding beds, and in this block the carbon ratio, as indicated by Carboniferous coals at one end of the block, was 60 or less.

The persistence of oil in this protected block justifies the hope that under similar conditions either oil or gas may be found in commercial quantities, and the structure at Early Grove described by Charles Butts lies in such a block. A long narrow basin, 60 to 70 miles long and 4 to 5 miles wide, lies just east of the prominent ridge known as Clinch Mountain. Sediments ranging from Cambrian to Devonian in age were thrust over this basin, and the fault on the east side of the basin permitted relief of much of the stress that would otherwise have adversely affected the sediments. Erosion has now here and there cut through the plate of older rocks and exposed limestones and shales of Mississippian and Devonian age, and it is in these beds that the oil or gas—more probably the latter since the carbon ratio ranges from 61 to 63—may be found.

The structure is at least reasonably favorable, for there is a very definite, sharply folded anticline within the basin, and a test 3,500 feet deep drilled on its crest should penetrate at least six formations which, at one place or another, carry oil or gas. It has the drawback that the reservoir would almost certainly be a limestone, and it does not offer possibilities on a scale that would attract a major company, but it is undoubtedly a possible source of gas for nearby towns in southwestern Virginia, and seems to carry more promise of oil or gas production than any other area in Virginia, so far as present knowledge indicates.

K. C. HEALD

PITTSBURGH, PENNSYLVANIA
June, 1927

Foldtani Szemle [Hungarian Review for Geology and Paleontology]. Published by the Geological Department of the Royal Hungarian Peter Pazmany University in Budapest, under the editorship of Professor Karl von Papp, Vol. 1, No. 1 (1927).

The *Foldtani Szemle* is the youngest of the geological serials. It has been founded by Professor Papp under the auspices of the geological department of

the University at Budapest and with the support of Graf Teleki, the minister-president of Hungary, and of Professor Cholnoky, chief of the scientific section of the Department of the Exterior. The purpose of the journal is:

to make its preferred task the scientific publication in regard to the mountains and high plateaus of the historic (i.e., pre-War) Hungary, but to give space, however, for papers on the geology of the neighboring Balkan states. The Hungarian geologists have a great deal of material from the old Hungary, from the Carpathians and their adjacent foothills and plateaus, the preparation of which will occupy them for several decades. Each successive number of this geological journal will be richly provided with such communications.

The first number, which has just appeared, sets a high standard. The papers are: an introductory one by Professor Papp; "The Geological Relations of the Vicinity of Valona in Albania," by H. von Bandat; "The Bauxite Deposits of the Trans-Danubian Mittelgebirge in Hungary," by K. R. von Telegd; "My Geological Researches in Western Serbia," by L. de Loczy, Jr., with a large-sized lithographed map of the geology of western Serbia. The papers are in German, French, and English. The paper is good, and the type and cuts clear and pleasing. The serial gives good promise of becoming a very important contributor to the advancement of geologic literature.

DONALD C. BARTON

HOUSTON, TEXAS
July 11, 1927

Petroleum Development and Technology in 1926. By MANY AUTHORS, MEMBERS OF THE PETROLEUM DIVISION, A.I.M.E. Papers presented before the division at Tulsa, Oklahoma, October 11–12, 1926, and at New York, February 15–17, 1927. American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th Street, New York City, 1927. 956 pp.; illustrated. Price, clothbound, $5.00.

The Petroleum Division of the American Institute of Mining and Metallurgical Engineers takes another forward step in its program of service to the oil industry in presenting this volume which includes over seventy papers relating the advances which have been made in the industry during the past year. These papers, with the accompanying discussions and symposiums, represent the contributions of 240 skilled technologists and engineers who stand at the front in their respective branches of the profession.

The volume has been divided into eight parts. In Part I, entitled "Production Engineering," the advances made in petroleum technology during 1926 are detailed, flooding problems are described, and recent developments in drilling and production practice are outlined. During the past year there has been a remarkable increase in the use of air and gas lifts in wells in the Mid-Continent fields, and several very timely papers describing the principles and methods of increasing the recovery of oil are contributed by men thoroughly familiar with

this branch of engineering. This symposium dealing with the newer methods of flowing wells should be brought to the attention of all oil company executives.

"Refining Technology" is the heading of Part II. Several papers are contributed by men of high standing outlining the recent developments made in this field, and considerable attention has been given to advances in the cracking processes.

Part III deals with "Transportation Engineering" and contains a single paper on the transmission of highly viscous oils, with the attendant discussion.

Under the heading of "Corrosion," Part IV includes a group of highly significant papers which bring to the attention of the industry at an opportune time the importance of corrosion problems. These contributions deal with the fundamentals of corrosion and the methods used in combating this evil in pipe lines, refineries, gasoline plants, pumping equipment and wells, and express the ideas of men who are actively engaged in reducing corrosion loss.

The annual review of the production of petroleum during 1926 is covered by the contributions in Part V, entitled "Production." In the several papers the various fields of the United States and foreign countries are reviewed by competent men, and the accompanying discussions bring out many interesting views as to future production in the areas covered by the reports.

Part VI deals with "Petroleum Economics," with several papers treating of the trend and position of crude oil and its various products.

Parts VII and VIII cover Round Table discussions on petroleum engineering, educational and research problems. These Round Tables were instituted for the first time during the year 1926, and brought out the ideas of educators, employers, and engineers in active practice.

In assembling the various papers which make up this volume, the American Institute of Mining and Metallurgical Engineers has made easily available a vast amount of authentic information which cannot fail to be indispensable to all petroleum engineers.

A. F. TRUEX

TULSA, OKLAHOMA
August 1, 1927

RECENT PUBLICATIONS

GENERAL

Journal of Paleontology, Vol. I, No. 1, July, 1927. Published by the Society of Economic Paleontologists and Mineralogists, under the editorship of Joseph A. Cushman. This is the first number of a new quarterly published by the recently organized special group within the American Association of Petroleum Geologists. 101 pp.; illustrated. Marcus A. Hanna, Secretary-Treasurer, Drawer C, Houston, Texas. Subscription price, $6.00 a year.

Petroleum Reference Book, 1927 edition. A compilation of facts pertaining to every branch of oil activity. Contains buyers' guide, technical section, and many

useful facts. Published by the American Oil Men's Association, 624 South Michigan Avenue, Chicago, Illinois. 265 pp.

Plants of the Past, by Frank Hall Knowlton. Princeton University Press, Princeton, New Jersey, 1927. 19 chaps., 90 figs. Price, $3.50.

"Gravity on the Earth and on the Moon," by Fred E. Wright. *The Scientific Monthly*, Vol. 24, May, 1927, pp. 448–62. *Paper No. 633* from the geophysical laboratory, Carnegie Institution of Washington. Of interest in connection with torsion-balance studies.

The Petroleum Register, 1927 edition. Published by Holland S. Reavis, 239 West thirty-ninth Street, New York City. International annual directory, statistical record, and equipment catalogue of the petroleum industry, with maps of principal producing and prospective oil territories. 608 pp. Price, $10.00.

Congrès Géologique International, Comptes Rendus de la XIV^e^ Session, en Espagne, 1926. First issue of the proceedings of the Fourteenth International Geological Congress, Madrid, Spain. Contains 6 papers on phosphates and pyrites. Issued by Instituto Geológico y Minero de España, Cristobal Bordiu, 12, Madrid, Spain. 323 pp., illustrated.

ARKANSAS

Outlines of Arkansas' Mineral Resources, by George C. Branner. Bureau of Mines, Manufactures, and Agriculture, and State Geological Survey, Little Rock, Arkansas, 1927. 352 pp., including oil and gas information, many maps and illustrations.

CANADA

"Preliminary Report on the Mineral Production of Ontario in 1926," by W. R. Rogers and A. C. Young. *Ontario Department of Mines Bulletin 60*. Toronto, 1927. Contains oil and gas statistics. Oil Springs field has been producing for 66 years. Total production of petroleum in Ontario for 1926 was 136,971 barrels. 28 pp.

"Natural Gas in 1925 and Petroleum in 1925," by R. B. Harkness. *Ontario Dept. of Mines*, thirty-fifth Annual Report, Vol. 35, Part 5 (Toronto, 1926). Gas production was 113,639,000 cubic feet less than in 1924. Thirteen fields produced 144,249 barrels of petroleum in 1925. Average production per well per year in the most productive field is 44 barrels. 69 pp.

ILLINOIS

"Illinois Petroleum." *Press Bulletin Series No. 10, State Geological Survey*, Urbana, Illinois. Describes structure of Centralia and Sandoval oil fields in Marion, Clinton, and Washington counties. Price, $0.25.

JAPAN

The Geology and Mineral Resources of the Japanese Empire. Imperial Geological Survey of Japan, Tokyo, 1926. Text, in English, accompanying a re-

vised edition of the "Geological Map of the Japanese Empire" on a scale of 1:2,000,000. 136 pp.

"A Study on the Oil-Bearing Beds in the Echigo Oil Field" by Tsunenaka Iki. *Journal of the Faculty of Engineering*, Vol. 16, No. 12 (January, 1927), pp. 241–79, Tokyo Imperial University, Tokyo. Charts and maps. In English.

NEW MEXICO

Tentative Correlation of Formations in New Mexico and Adjoining Parts of Neighboring States. Compiled by M. Grace Wilmarth, secretary of Commission on Geologic Names, U. S. Geol. Survey, Washington, D.C., June, 1927. Chart for free distribution.

OKLAHOMA

Structural Map of Red River Oil Field, by B. H. Tucker. U. S. Geol. Survey, Washington, D.C., or Muskogee, Oklahoma. Contours on oil-bearing sand.

The following new reports may be obtained from the Oklahoma State Geological Survey, Norman, Oklahoma:

"Geology of Garvin County," by Robert H. Dott. *Bulletin 40-K*. Price, $0.30.

"Geology of Wagoner County," by Phillip Boyle. *Bulletin 40-L*. Price, $0.30.

"Geology of Beckham County," by Frank Gouin. *Bulletin 40-M*. Price, $0.30.

RUSSIA

"La Région Pétrolifère de Bakou," by V. Stchepinsky. *Annales de l'Office National des Combustibles Liquides*, No. 2 (June, 1927), pp. 329–53. 85, Boulevard du Montparnasse, Paris (6e). Stratigraphic and structural description of oil fields of Southern Russia, with tables and maps.

TEXAS

"Well Records in Pecos County, Texas." Advance chapter from bulletin on *Geology and Mineral Resources of the Fort Stockton Quadrangle*, Bur. of Econ. Geol., Univ. of Texas, Austin, Texas, May, 1927. 32 pp.

WYOMING

Thirteenth Biennial Report of the State Geologist of the State of Wyoming, by Albert B. Bartlett. Office of the State Geologist, Cheyenne, Wyoming. For period of October 1, 1924, to and including September 30, 1926. Tabulation of geological correlations and oil structures. 28 pp. and map.

THE ASSOCIATION ROUND TABLE

PROJECTS IN PETROLEUM RESEARCH[1]

The Central Petroleum Committee of the National Research Council has recommended to the American Petroleum Institute thirty-two projects in scientific research in the geology, physics, and chemistry of petroleum. Practically all of these projects have been approved and assigned by the Institute or organizations specially equipped to carry on the work. The projects, with corresponding project numbers and assignments as given in the *A. P. I. Bulletin*, Vol. 8, Nos. 20 and 27, March 31 and May 4, 1927, are as follows:

	Geology	Assignment
1.	Generation of Oil in Rocks by Shearing Pressures	University of California
3.	Studies of Source Rocks in the Micro-Furnace	U. S. Geological Survey
4.	Origin and Environment of Source Sediments	Washington, D.C.
5.	Diatoms as Source of Oil	Stanford University
22.	Thicknesses and Characters of the Strata in the Deeper Sedimentary Basins of North America	Washington, D.C.
23.	Limestones and Dolomites as Reservoir Rocks	University of Illinois
24.	Structural Relations of Beds That are Separated by Converging Strata	University of Oklahoma
	Physics	
6.	The Separation, Identification and Determination of the Chemical Constituents of Commercial Petroleum Fractions	U. S. Bureau of Standards
7.	Catalytic Methods Applied to Petroleum Hydrocarbons	Princeton University
9.	Analysis of Hydrocarbons by the Time Positive-Ray Method	California Institute of Technology
10.	Analysis by Fractional Distillation from Absorbent Materials (Charcoal, Silica Jell, etc.), Both of Light and Heavy Members of the Hydrocarbon Series	California Institute of Technology
11.	Analysis of the Gradual Oxidation Prior to Ignition of Fuels in Internal Combustion	

[1] For previous information about progress of petroleum research and the research activity of the American Association of Petroleum Geologists, see this *Bulletin*, Vol. 11, No. 6 (June, 1927), pp. 644-47.

	Physics	Assignment
	Engines, and the Relation of Such Oxidation to Detonation	California Institute of Technology
12.	Accurate Comparison by Viscosity Methods Developed by Millikan of the Viscosities, and Hence of the Mean Free Paths of Ring and Chain Hydrocarbons of the Same Molecular Weight and Composition	California Institute of Technology
13.	Determination of Physical Properties of Petroleums and Petroleum Products	University of Michigan
25.	Determination of Geothermal Gradients in Oil Fields on Anticlinal Structure	University of Oklahoma, University of Texas, University of California
26.	Determination of the Thermal Conductivity of Gases and Its Application to the Precise Analysis of Hydrocarbons and Other Gases	U. S. Geological Survey
27.	The Displacement of Petroleum Oils from Oil-Bearing Sands by Use of Selected Aqueous Solutions	University of Michigan
32.	Study of the Equation of State of Certain Easily Liquefiable Hydrocarbons	
	Chemistry	
2.	Action of Oxygen (and Air) on Cyclopentane and Cyclohexane Hydrocarbons with Side Chains	
8.	The Effect of Electric Discharge upon Gaseous Hydrocarbons	University of Minnesota
14.	Preparation of Pure Typical Hydrocarbons and a Study of Their Behavior When Heated Alone and with Catalysts	California Institute of Technology
15.	A Study of the Cyclopentane Fraction of Southern California Petroleum	Johns Hopkins University
16.	Isolation and Investigation of Thermo-Labile Hydrocarbons Present in Petroleum	Harvard University
17.	Isolation and Study of the Sulphur Compounds Present in Petroleum	Northwestern University
18.	Non-Catalytic Thermal Decomposition of Pure Hydrocarbons and Related Compounds	Northwestern University
19.	A Study of the Relative Rates of Reaction of the Olefines	Massachusetts Institute of Technology
20.	Isolation and Investigation of Nitrogen Compounds Present in Petroleum	University of Texas
21.	Determination of Physical and Chemical Properties of All Types of Sulphur Compounds Present in Petroleum	Mississippi College

Chemistry	Assignment
28. A Study of the Reactions of a Number of Selected Organic Sulphur Compounds	Johns Hopkins University
29. An Investigation of the Heat Capacities and Free Energies of Some Typical Hydrocarbon Compounds	
30. A Study of the Metallic Constituents of Crude Petroleum	Pennsylvania State College
31. The Action of Sulphuric Acid on Paraffin Hydrocarbons	University of Oklahoma

For information of the Association members, an outline[1] of the geological projects, giving condensed statement of each project, plan of operation, and institutions and men engaged in the work, follows. Considerable progress has been made on all of the geological projects. Work has continued on projects 3, 4, and 23 for more than a year.

PROJECT 1: GENERATION OF OIL IN ROCKS BY SHEARING PRESSURES

Most geologists believe that petroleum is generated from fossil organic matter by geophysical and geochemical processes of pressure and heat exerted throughout long periods of time. Many believe it to have been generated by biochemical decomposition processes at the time of deposition of the organic débris. The belief that it originates in the former way, that is, by natural geological distillation in the crust of the earth, implies the restriction of oil fields to areas subjected to compressive stresses.

Proposed plan of research.—It is planned to conduct shearing-pressure tests with varying factors of time, pressure, temperature, catalysis, and solutions. The plans are based on the assumption that oil is generated from commonly supposed "mother rocks"—typical oil shales or marine bituminous (carbonaceous) shales—under loading of superposed strata, by pressures (mainly intermittent horizontal thrusts) operating through long periods, with heat of depth of burial, heat of friction, and heat of chemical change, and with added pressures of the resulting gases and oils. Great pressures will be exerted variably, intermittently, and through considerable periods, with conservation or maintenance of the heat generated or proved normal to the process.

Locale.—Department of Geology, University of California, Berkeley, Calif.

Personnel.—Director, Professor Warren J. Mead; Junior Research Fellow, J. E. Hawley.

PROJECT 3: STUDIES OF SOURCE ROCKS IN THE MICROFURNACE

This study has for its immediate object the observation and determination, by means of a microfurnace, of the temperatures at which the optically distinguishable fossil components and their derivatives in the varied organic conglomerates that make up the different types of bituminous shales volatilize.

[1] Summarized from *A. P. I. Bulletin*, Vol. 8, No. 20, March 31, 1927.

The results of preliminary work on this project were published in this *Bulletin* in September, 1926.

Plan of operation.—To date the microthermal observations cover several oil shales, cannels, carbonaceous shales, coals, and bogheads. This study is in the first stage, and the observations are but partially interpreted. The microthermal observations should be followed by distillations of the same rocks under the same conditions in a special retort, so that test cuts may be taken off at the temperatures corresponding to the observed changes in the components noted under the microscope.

The detailed chemical study of these cuts, the third stage in the procedure, should not only throw invaluable light on the importance of each of the readily visible components in the rock and of the organic groundmass as sources of distillates generated under different processes or conditions, but it should also indicate, roughly, at least, the quality or qualities of the distillate yielded by each. It should go far toward tracing the qualities as well as the quantities of the distillates back to their organic sources.

Locale.—Laboratory of U. S. Geological Survey, Washington, D.C.

Personnel.—Director, Dr. David White, senior geologist, U. S. Geological Survey; Research Associate, Miss Taisia Stadnichenko.

PROJECT 4: ORIGIN AND ENVIRONMENT OF SOURCE SEDIMENTS

This project covers the study of oil shale or supposed mother-rock sediments in the making. It requires the examination of the conditions of deposition, of the ingredient materials, and of the compositions of the different types of mother rocks laid down in different environments and in marine and fresh water. In this domain there are many localities where sediments thought to be of critical types should be in process of desposition. Such areas are Chesapeake Bay, Currituck Sound, indentations along the Gulf of Mexico, both in the coast of the United States and Mexico, the Gulf of California, and perhaps places in Puget Sound. Every advantage will be taken of any available oceanographic exploration.

Locale.—Headquarters, Washington, D.C.

Personnel.—In charge of Advisory Committee: W. A. J. M. van der Gracht, geologist; Austin H. Clark, zoölogist and oceanographer; T. Wayland Vaughan, paleontological sedimentarian and oceanographer; Research Associate, Dr. Parker D. Trask.

PROJECT 5: DIATOMS AS SOURCE OF OIL

Many geologists believe that diatoms are the principal source of the oil in the great oil fields of California. Most geologists concede that diatoms *may* be a very important oil source. For the purpose of determining whether petroleum originates directly or indirectly from diatoms, this project requires a thorough biological and chemical study of living diatoms and a supplementary study of fossils in the thick diatomaceous shales of California.

Plan of operation.—(1) Study of conditions under which a diatom epidemic occurs. (2) Establishing nature of the oil of the diatom and its relations to photo-synthesis. (3) Studies of the conditions of the expulsion of oil from the diatoms. (4) Study of the bacterial decomposition of masses of diatoms with particular reference to the oil, keratin, and chlorophyll.

Locale.—Headquarters, Stanford University, Palo Alto, California.

Personnel.—Director, Professor C. F. Tolman; Junior Research Fellows, T. Hashimoto and Lewis A. Thayer.

PROJECT 22: THICKNESSES AND CHARACTERS OF THE STRATA IN THE DEEPER SEDIMENTARY BASINS OF NORTH AMERICA

Existing information on the thicknesses, characters, origins, sources, and histories of the sediments that fill the major synclinal basins of North America will be compiled, studied, and systematized. Where essential to the project, new data will be gathered. Limited field examinations will be necessary.

Objectives.—(1) Information regarding known and inferred depths to the crystalline basement rocks in the major synclines of North America. (2) Information regarding the probable distribution, depths, and changes in character of important formations. (3) Deductions concerning the maximum depths to which drilling must ultimately be carried. (4) Data that will permit more exact calculation of gravity values, and reasons for apparent anomalies. (5) Data of value in seismologic research. (6) Modifications of present conceptions of geologic history and of paleogeography.

Locale.—All major synclines of North America to be considered, but actual field work will be limited to those east of the Rocky Mountains. Headquarters, Washington, D.C.

Personnel.—Under direction of the following Advisory Committee: R. S. Bassler, U. S. National Museum; W. E. Wrather, Dallas, Texas; H. D. Miser, U. S. Geological Survey; C. H. Wegemann, New York City; Eliot Blackwelder, Stanford University; Research Associate, Dr. Raymond C. Moore, U. S. Geological Survey.

PROJECT 23: LIMESTONES AND DOLOMITES AS RESERVOIR ROCKS

There are two principal classes of reservoir rocks of petroleum and natural gas. One of them is made up primarily of porous limestones and dolomites. No careful study of this type of reservoir rock has been made, and no compilation exists to show either the prevalence of such "sands," or the peculiarities of the oils that characterize them, especially the existence of sulphur.

Plan of operation.—It is proposed to make a library and laboratory study of these reservoir beds with some supplementary field studies. Their occurrence and characteristics, including origin and composition, must be studied. The behavior of wells that produce from them and the character of oil they yield must also be studied.

Objectives.—(1) Much-needed detailed information concerning nature and origin of limestone and dolomite reservoir rocks. (2) Statement of behavior of wells that produce from such reservoir rocks. (3) Start on explanation of prevalence of sulphur in limestone oils.

Locale.—Department of Geology, University of Illinois, Urbana, Illinois.

Personnel.—Director, Dean A. H. Daniels; Research Fellow, Professor W. V. Howard.

PROJECT 24: STRUCTURAL RELATIONS OF BEDS THAT ARE SEPARATED BY CONVERGING STRATA

Often the only evidence at the disposal of the geologist in his efforts to interpret geologic structure is that presented by outcropping strata. However, it is seldom that the structure of the oil-bearing stratum exactly parallels that of these out-cropping strata. One of the most prevalent reasons for difference in configuration and in position between surface and deep-lying beds is the presence of converging strata that are appreciably thinner on one side of an oil field than they are on the other.

Plan of operation.—The research assistant will study and summarize present knowledge and belief on the subject considering both published discussions and available examples of oil field and regional structure where variations in thickness in the beds between critical horizons have been determined.

Selected areas where converging beds are known to occur will be studied, and an experimental attack to attempt to produce artificially the natural relations will be carried on.

Objectives.—(1) Published record of determined conditions in selected areas, and apparent explanations. (2) Experimental determination of effect of converging strata in destroying parallelism and vertical superposition of folds. (3) Contribution to knowledge regarding reasons for certain convergences. (4) Presentation of data concerning control apparently exerted by the nature of the converging strata that may be involved.

Locale.—Department of Geology, University of Oklahoma, Norman, Oklahoma.

Personnel.—Director, Professor V. E. Monnett; Research Assistant, H. Andrew Ireland.

GEOLOGICAL NOTES

As a building is composed of an aggregate of many small bricks or building stones, so a science is developed by the gathering together of many facts, perhaps seemingly unrelated, and their synthesis, under the guidance of hypothesis, into a body of organized knowledge and a practical working system. Without the bricks, small though they are, the building could not be; without a great body of recorded and indexed facts and observations gathered by many workers in diverse places and with diverse points of view, a science cannot develop.

Petroleum geology is a new science. Very much remains to be learned and to be explained. It can progress only as new information is gathered and made available. Information which is obtained and not made generally available is likely to be lost and to fail to contribute toward the advancement of the science.

Much of the information needed as a foundation for further advances in petroleum geology is of a kind which is accumulated as minor items of fact or observation, such as active petroleum geologists are continually encountering, which excite temporary interest and thought, but which in themselves are not big enough or seemingly important enough, or, perhaps, not well enough understood to form the basis of a major contribution to the *Bulletin* or other similar scientific journal. Hence, as a rule, no permanent public record is made and they are soon forgotten.

Yet it is just such items which are the necessary building stones of the science. The interesting fact which the field geologist may have noticed, discussed with a few of his immediate associates, and then forgotten may have been precisely the missing key to an important geologic problem for which some other investigator had been vainly searching. Unless it is recorded in an available place it is lost.

The "Geological Notes" section of the *Bulletin* is specially designed for the recording of such items of fact or theory which are not in themselves important enough or big enough to form the basis of a major paper. An item published in "Geological Notes" is seen by readers all over the world; it is indexed; and it thus becomes available to all investigators who may be working on the subject with which it deals.

The amount of valuable source material of petroleum geology which exists in the minds and note books of field geologists is enormous, entirely aside from material of a confidential nature. If it could be made generally available the science would undoubtedly be advanced by several years. Wherever a group of field men gathers to "talk shop," one hears plenty of interesting things of the sort for which the "Geological Notes" section was created, yet comparatively little of this ever finds its way into the records.

The men in the field who are constantly dealing with geological problems at first hand are the ones who are most frequently uncovering interesting and significant scientific items, but they are the ones who are least likely to stop to prepare an elaborate paper. Their time is limited, reference works are not at hand, they may never have prepared a paper for publication, or they are not sure that what has interested them is really new or so significant as it seems.

To the men in the field, to the younger members of the Association, and to all of the members who from time to time make observations or note facts which seem to have a bearing on some of the larger problems of petroleum geology in any of its branches, I would say in behalf of the editorial group: Write up your observations while they are fresh; be careful to get the facts straight and to record them accurately, whether or not you understand their full meaning; and

send them in for publication in "Geological Notes." If you are not sure that your observations are new, let the editorial board decide, and if your contribution is turned down, try again. It is decidedly worth while. It will help your science, your fellow-workers, and yourself.

JOHN L. RICH

NON-MEMBER SUBSCRIPTIONS TO THE BULLETIN

Recently a friend asked me if it were possible for a person who is not a member of the A.A.P.G. to receive the *Bulletin* of the Association. He was assured that subscriptions from non-members were welcome. The question led me to wonder if there might not be a great many people who would find the *Bulletin* useful and who would be glad to become regular subscribers if that possibility were called to their attention—people who are interested in what petroleum geologists are doing, but who are not eligible for membership. Many of the independent oil operators, for example, are more or less interested in geology, and might be included in this class.

From every standpoint it is desirable to have the *Bulletin* distributed as widely as possible. A wider circulation to outside subscribers would spread a knowledge of what the Association is doing, and incidentally materially increase the net income of the Association, at a very small increase in overhead.

These paragraphs are written to remind the Association members of a possible means by which they may render a distinct service, not only to the Association, but also to any of their acquaintances who might appreciate receiving the *Bulletin*, by calling to their attention the possibility of a non-membership subscription.

J. L. R.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

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Homer M. Wilson, Del Rio, Tex.
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Jay Pendleton Wood, Denver, Colo.
Charles M. Rath, Max W. Ball, John W. Finch

FOR TRANSFER TO ACTIVE MEMBERSHIP

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James R. Wylie, Jr., Pittsburgh, Pa.
L. G. Huntley, Roswell H. Johnson, R. E. Somers

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

Meet me at the A. A. P. G. booth at the Fourth International Petroleum Exposition at Tulsa, September 24–October 1. The exposition is of educational, scientific, and economic value. The Association is to have space in the new special building for technical and scientific exhibits.

The First National Fuels Meeting is to be held at St. Louis, October 10–13. This is arranged by the fuels division of the American Society of Mechanical Engineers, but it will appeal to all interested in the production, transportation, and application of fuels. The program includes the names of national authorities. The chairman of the general arrangements committee is Victor J. Azbe, 6625 Delmar Boulevard, St. Louis, Missouri.

LEON J. PEPPERBERG, geologist and engineer, American Exchange National Bank Building, Dallas, Texas, was in New York City and other eastern places on business during August.

E. R. AMES is Mid-Continent manager for the Elliott Core Drilling Company, with headquarters at Houston.

F. C. MERRITT, with the Elliott Core Drilling Company at Los Angeles, recently visited Houston on business.

J. H. JENKINS, vice-president in charge of Texas operations for the Tidal Oil Company, with headquarters at Fort Worth, visited at his boyhood home in Petrolia, West Virginia, last July.

CARL ST. J. BREMNER has moved to 460 G. St., Oxnard, California.

W. F. WEED has resigned from the Gulf Production Company's geological and geophysical department to go with the Weed-Gayle Oil Company to study cap-rock drilling at Pooling dome.

CALVIN T. MOORE, of W. C. McBride, Inc., has moved from Oklahoma City to 1615 Fort Worth National Bank Building, Fort Worth, Texas.

H. D. MISER, of the geologic branch of the U. S. Geological Survey, is in charge of the section of geology of fuels.

W. F. HOWELL, of the geological staff of the Marland Oil Company of Colorado, has been working in Montana and Wyoming during the past several months.

G. WITTEVEEN, who has been for some time with the Caribbean Petroleum Company at Maracaibo, has left Venezuela. Mr. Witteveen's address is "De Swarte Kamp," Geldermalsen, Holland.

FRANK REEVES is on a furlough of four months from the U. S. Geological Survey, while doing exploratory geologic work in western Canada.

DEAN WINCHESTER, consulting geologist of Denver, returned in July from seven months of exploration work in Venezuela for the Sinclair Exploration Company.

W. O. GEORGE is in charge of geological exploration for the Tropical Sun Oil Company in Colombia.

JOHN G. BARTRAM, of the Midwest Refining Company at Denver, made a survey of the LaBarge district in July.

C. E. DOBBIN, assistant chief of the fuels section in the U. S. Geological Survey, left Washington late in July to visit the Survey's coal and oil parties in the Rocky Mountain region. He will also carry out special studies of certain types of Rocky Mountain coals in connection with his work as a member of the Sectional Committee on the Classification of Coal of the American Society for Testing Materials.

RALPH E. DAVIS, of Pittsburgh, visited the California and Mid-Continent fields during the summer.

J. M. LOVEJOY, vice-president of the Amerada Petroleum Corporation, spent the summer at Bass Rock, Massachusetts.

ROBERT REID, of the Empire Gas and Fuel Company, was transferred from Bartlesville to Fort Worth, to take charge of subsurface work in Texas.

W. T. GRISWOLD lives at Northeast, Pennsylvania.

L. S. CORYELL is consulting geologist in west Texas for the Philmack Oil Company.

GEORGE A. KROENLEIN is living at the Tourist Hotel, Del Rio, Texas.

FRANK R. CLARK, chief geologist of the Mid-Kansas Oil & Gas Company, is in charge of geological work being conducted at Alpine, Texas.

L. A. SCHOLL, JR., and LLOYD NORTH, of The Texas Company, visited west Texas in July.

T. H. KERNAN moved from San Angelo to St. Louis in July

H. B. GOODRICH, consulting geologist of Tulsa, spent July at Fort Stockton, Texas.

V. E. COTTINGHAM, formerly of the Exploration Company, has organized a royalty company in San Angelo, Texas.

C. P. WATSON is president of the Federal Royalty Company, Inc., and is living at the Fort Worth Club, Fort Worth, Texas.

A. E. FATH is working in west Texas with headquarters at the St. Angelus Hotel, San Angelo.

JOSEPH E. MORERO is subsurface geologist for the Skelly Oil Company at San Angelo.

F. H. LAHEE, of the Sun Oil Company, spent the summer in Europe on business.

P. R. YEWELL is in charge of geological work of the Skelly Oil Company in west Texas.

IRA OTHO BROWN, of the Mid-Kansas Oil & Gas Company, has been transferred from San Antonio to San Angelo.

J. BASIL WAGNER is living at Chandler, Oklahoma.

H. N. CORYELL, instructor in geology and paleontology, Columbia University, New York City, and consulting paleontologist for the Pure Oil Company, Tulsa, Oklahoma, has collected, mounted, arranged alphabetically, and edited six volumes of photographs of fossil Ostracoda plates with explanatory notes and correlation charts. The work includes 538 photographic prints from 191 papers written by 73 different authors.

R. S. MCFARLAND of the Twin State Oil Company and Luther H. White (alias McWhite) of the J. A. Hull Oil Company, both of Tulsa, were reported somewhere in the Rocky Mountains in July.

C. G. CARLSON resigned from the Twin State Oil Company last July to accept a position with the Peerless Oil & Gas Company of Tulsa. Mr. Carlson spent his vacation the latter part of July in Michigan.

G. F. ALDRICH, geologist for the Independent Oil & Gas Company, is the author of a subsurface map of the Church-Fields and Gulf-McElroy pools contoured on the top of the lime series, published on p. 73 of the *Oil & Gas Journal* for July 14.

GEORGE R. ELLIOTT of Hollywood, California, published a paper on "Alamitos Heights, Most Productive Area of Sea Beach District," with maps and charts, in the *Oil Weekly* of July 1.

A. W. LAUER, division geologist of The Texas Company at Tulsa, took his vacation last July in the Yellowstone National Park.

EDWIN A. MCKANNA of Berkeley, California, geologist for the Mexican Seaboard Oil Company, was in San Antonio in July.

ELLIOTT M. MITCHELL, graduate of the University of California in 1924, and recently employed by the Phillips Petroleum Company, died at Tulsa, Oklahoma, July 11, 1927.

P. C. DEAN has a consulting office in Eastland, Texas, in the firm name of Dean & Adkisson, Inc.

JOHN L. RICH was in Illinois on business last July.

R. F. RYAN is associated with the Vacuum Oil Company, in the geological department. Mr. Ryan's headquarters is at San Angelo, Texas.

DILWORTH S. HAGER is chief geologist for the Vacuum Oil Company, with headquarters at Houston.

C. DON HUGHES, of the Empire Gas & Fuel Company at Amarillo, Texas, has returned from a brief vacation.

GEORGE C. MATSON, of Tulsa, has been with his family during the summer at Sullivan's Island off the coast of South Carolina.

JEAN A. HOEKSTRA, of the geological department of the Caribbean Petroleum Company at Maracaibo, Venezuela, has been traveling in the United States during the past several months.

EVERETT CARPENTER has resigned from the Mississippi Valley Oil Company and is engaged in consulting work at Bartlesville, Oklahoma.

CHARLES W. MILLER has completed an examination of Johns Valley, Oklahoma, Sec. 4, T. 1 S., R. 16 E., for the Oklahoma Geological Survey.

E. O. MARKHAM, of the Carter Oil Company at Tulsa, was in Missouri spending his vacation at his home last July.

DONALD K. WEAVER, of the California Petroleum Corporation, has been transferred to Sunburst, Montana.

ROY WELSH, geologist for the New England Oil & Refining Company of Tulsa, was in west Texas in July.

J. E. EATON, consulting geologist of Los Angeles, was busy in the San Joaquin Valley in August.

A. L. JONES is with the Sun Oil Company at Cotulla, Texas.

E. G. SINCLAIR was killed on June 25 by the accidental discharge of his rifle while he was hunting on his ranch near Kalispell, Montana.

S. C. STATHERS, chief geologist for the Standard Oil Company of Louisiana, Shreveport, recently looked over wild-cat areas and activities in Mississippi.

W. J. LLOYD and R. G. CARPENTER, of the U. S. Geological Survey, were at Tucumcari, New Mexico, in July, working on a topographical map of the section from Vaughn to Bryantine.

HAROLD J. COOK, recently of Denver, Colorado, is situated at Agate, Nebraska.

JAMES N. HOCKMAN, of The Texas Company, has moved from Crossett, Texas, to Guthrie, Oklahoma.

R. B. RUTLEDGE, of the Barnsdall Oil Company, has moved from Winfield to Wichita, Kansas. His address is 607 Union National Bank Building.

E. V. H. BAUSERMAN, formerly with Humphreys Corporation at Houston, has accepted a position with the Roxana Petroleum Corporation at Palestine, Texas.

ROY P. LEHMAN has moved from Shawnee to Norman, Oklahoma.

THEODORE A. LINK, who received a doctorate degree from the University of Chicago, has returned to the Imperial Oil, Ltd., of Canada, and is now stationed at Calgary, Alberta, in charge of the geological offices.

C. I. ALEXANDER is instructor in the department of biology and geology at Texas Christian University at Fort Worth.

LLOYD E. WELLS may be addressed at 537 Harvey-Snider Building, Wichita Falls, Texas.

H. F. DAVIES is situated at Billings, Montana, with the Standard Oil Company of California.

CARROLL H. WEGEMANN, of the Pan American Petroleum and Transport Company, 120 Broadway, New York City, was in southwestern Texas and Mexico last July with E. A. HALL, division geologist at Tampico.

NILES B. WINTER has a new address—Box 472, Pecos, Texas.

E. P. PHILBRICK is with the White Eagle Oil & Refining Company at Abilene, Texas.

PAUL A. SCHLOSSER is working for the Phillips Petroleum Company at Fort Stockton, Texas.

ALBERT G. WOLF, of the Texas Gulf Sulphur Company, has moved his office from the Second National Bank Building to 1031 Post-Dispatch Building, Houston.

E. HAZEN WOODS is with the Atlantic Oil Producing Company at Shawnee, Oklahoma.

LOUIS W. FREEDMAN, who was in Mexico a few months ago, recently spent several weeks in Washington and New York. Mr. Freedman was living at the Westbrook Hotel, Fort Worth, Texas, last July.

FREDERICK W. GARNJOST has joined The Texas Company at Bayonne, New Jersey, in a technical capacity.

RUSSELL W. GRIMES is connected with the Roxana Petroleum Corporation at San Angelo, Texas.

G. C. LEMLEY has changed his address from Wichita Falls, Texas, to Mount Morris, Pennsylvania.

BRUCE C. MCKAGUE, formerly with the Roxana Petroleum Corporation at San Angelo, moved to Cross Plains, Texas, in June.

JOHN M. MUIR, recently in Baghdad for the Turkish Petroleum Company, Ltd., is at 16 Anwoth Villas, Corstorphine, Edinburgh, Scotland.

FRANK B. NOTESTEIN of Wooster, Ohio, has gone to Azua, Dominican Republic. His post office address is Apartado 21.

SIDNEY PAIGE went to San Angelo, Texas, in June.

ROLAND B. PAXSON, recently living in Houston, is now at 3711 Granada Street, University Park, Dallas, Texas.

ROBERT S. CHRISTIE, of the Marland Oil Company of Texas, has moved from Borger to Breckenridge.

WITHERS CLAY, chief geologist for the Woodley Petroleum Company, returned to his headquarters at Shreveport, Louisiana, last June. Mr. Clay had been working in Brownwood, Texas.

WILLIAM W. CLAWSON, of the Indian Territory Illuminating Oil Company, left Ada in June and is now situated in Bartlesville, Oklahoma.

LOUIS E. COTULLA, formerly of the Blackstone Oil Company at Fort Worth, is now with the Phillips Petroleum Company at Cisco, Texas.

EDWARD B. DANA is at Belpre, Ohio.

W. A. DAWSON has moved from Guthrie to Oklahoma City. His address is 2201 Classen Boulevard.

WILLIAM R. GAHRING may be reached through Box 520, Shawnee, Oklahoma.

CHARLES N. GOULD, state geologist of Oklahoma, spent his vacation with his family in Colorado last July.

DONALD MCARTHUR, who was at Leland Stanford, Jr., University the past year, is now at Medellin, Colombia, S. A. He may be addressed in care of Consulado Americana.

S. SPENCER NYE, junior geologist with the U. S. Geological Survey, is stationed at Roswell, New Mexico.

HENRY V. HOWE, professor of geology at Louisiana State University, Baton Rouge, spent part of the summer in Colorado.

W. J. JACKSON is working for the Louisiana Oil Refining Corporation at Shreveport.

H. T. BECKWITH has joined the geological force of the Transcontinental Oil Company at Fort Worth, Texas.

FRED M. BULLARD has moved to 310 West Gray, Norman, Oklahoma.

E. P. CAMPBELL, of the Marland Oil Company, is stationed at Big Spring, Texas.

RUSSELL S. TARR, consulting geologist of Tulsa, spent the summer at Gloucester, Massachusetts.

F. S. HUDSON has moved from Los Angeles to 1625 Opechee Way, Glendale, California.

H. J. STEINY, assistant geologist of the Associated Oil Company at Los Angeles, California, has returned from a stay of two weeks in the Sierra Nevadas.

MAX MUEHLBERG, of Aarau, Switzerland, is the author of "Geophysical Methods as Applied to Oil Finding," which is published as an appendix to a new book, *Outlines of the Occurrence and Geology of Petroleum*, by I. A. STIGAND.

FRANK W. DEWOLF is manager for the Louisiana Land and Exploration Company, Houston, Texas.

HOWARD CLARK of the War Department is collecting data for the Mississippi River Commission.

G. L. LAMBERT and DEAN MCGEE left for Peru on July 24 to carry on geological work for Phillips Petroleum Company.

E. A. STILLER, chief geologist of the Arkansas Fuel Oil Company at Shreveport, Louisiana, has returned from a vacation trip with Mrs. STILLER to Florence, Kansas.

A. ROGER DENISON, of the Amerada Petroleum Corporation, has been transferred from Tulsa to Fort Worth.

R. F. SCHOOLFIELD, consulting geologist, has moved from Laredo to San Antonio, Texas.

MERLE F. GUNBY represents the Vacuum Oil Company at Laredo.

CECIL N. HOUSH, of the Gulf Production Company, has been working at Center, Texas.

MILO M. ORR and E. BÖSE, of the Standard Oil Company of California, have headquarters at the Robert E. Lee Hotel, Laredo, Texas.

PAUL W. MCFARLAND, of the Sun Oil Company, has been transferred from Laredo to San Antonio.

THE CHAMBER OF COMMERCE OF DENISON, TEXAS, has published a pamphlet giving the logs of wells drilled in Grayson County.

LEW SUVERKROP described in the *Oil Weekly* for July 22, 1927, a new formation sampler to secure specimens from the walls of wells.

HALE B. SOYSTER, supervisor, Mid-Continent district, U. S. Geological Survey, described the oil- and gas-leasing operations of the Survey in the *Oil Weekly* for July 22, 1927.

N. H. DARTON, of the U. S. Geological Survey, spent the summer in west Texas on the areal geological map of the state.

F. W. PENNY has opened an office in the Cosden Building, Tulsa.

CARROLL H. WEGEMANN, of the Pan American Petroleum and Transport Company of New York City, visited Mexico in July with E. A. HALL, who is division geologist at Tampico.

ALFRED CUMMING and GEORGE A. KROENLEIN, of Del Rio, Texas, located the anticline in northwestern Val Verde County on which O. O. OWENS drilled a gas well in July.

CHARLES BYERS mapped the Goleta structure in California for the Plymouth Oil Company.

CHARLES J. HARES, chief geologist for the Ohio Mexican Oil Company, has moved to California.

O. A. LARRAZOLA, JR., has charge of the geological work of the Huasteca Petroleum Company at Del Rio, Texas.

PAUL L. APPLIN, of the Chesapeake Petroleum Company and J. S. Cosden, Inc., spent part of the summer in South Dakota watching a drilling well.

RAYMOND C. MOORE and F. B. PLUMMER have re-examined critical horizons in the Pennsylvanian section of north-central Texas to correlate them with the section in Oklahoma. Mr. Moore is studying the sedimentary basins of the Mid-Continent oil fields for the Central Petroleum Committee of the American Petroleum Institute.

C. E. DECKER spent the summer in the Arbuckle Mountains under the auspices of the Oklahoma Geological Survey.

W. C. SPOONER, of Shreveport, is consulting geologist for the Arkansas Geological Survey.

The new colored areal geological map of New Mexico will be published soon by the U. S. Geological Survey.

The U. S. Geological Survey has issued from its Muskogee, Oklahoma, office a subsurface structure contour map of the Red River oil pools north of Wichita Falls, Texas. B. H. TUCKER prepared the map.

L. DAVID WOSK, of Tulsa, is temporarily situated at Shawnee, Oklahoma.

W. IRWIN MOYER, of Philadelphia, has returned from an extended trip abroad.

HARRY R. JOHNSON, consulting geologist of Los Angeles, California, has moved his office to 837–38 Roosevelt Building.

F. A. SUTTON, of the Standard Oil Company at Buenos Aires, has been working in the Bolivian bush.

WILLIAM QUILLIAM was at Fowlerton, Texas, during the summer.

S. F. SHAW, consulting engineer in charge of gas-lift installations for the Carter Oil Company, Tulsa, enjoyed a month's vacation last July.

J. WALLACE BOSTICK, of Dallas, spent several weeks in the East this summer.

ROSWELL H. JOHNSON, of the University of Pittsburgh, spent the summer in Europe.

C. I. JENNINGS, district geologist for the Continental Oil Company at Denver, toured Texas last July on company business.

THE WEST TEXAS GEOLOGICAL SOCIETY met at San Angelo, July 9. Out-of-town attendants were LON D. CARTWRIGHT of Colorado City, Texas, R. F. RYAN of San Antonio, DILWORTH S. HAGER of Houston, and A. P. LOSKAMP of Cisco, Texas.

KENT K. KIMBALL, consulting geologist, National Bank of Commerce, Tulsa, was in Chicago during July.

The office of the U. S. Bureau of Mines at Dallas, Texas, is now at 308 Federal Building. This change of address affects the following men: H. B. HILL, CHASE E. SUTTON, and E. J. DEWEES.

J. D. SEARS of the geologic branch of the U. S. Geological Survey began field work in the Tongue River coal district of southeastern Montana last July.

CHARLES H. PISHNEY and LOUISE CORINNE BAKER were married in the First Presbyterian Church at Tulsa, Oklahoma, July 20. Mr. Pishney is employed by the Carter Oil Company.

E. DEGOLYER, president, and H. F. BAIN, secretary, of the American Institute of Mining and Metallurgical Engineers, were in San Francisco August 13 and 14 attending the meeting of the local members.

A. A. HASSAN is continuing his study of the Marathon Fold in western Texas.

E. G. SHAKLEY of the Comar Oil Company has moved from Braman to Marland, Oklahoma.